Modern Methods and
Materials for Teaching Science

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MODERN METHODS AND MATERIALS FOR TEACHING SCIENCE

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Preface

THIS book has a two-fold purpose: (1) to be a textbook for those courses in methods of teaching science which are now being given in many colleges and universities; (2) to be a source book of information for those teachers of science, at whatever level they may be working, who wish to keep up to date with modern trends in the teaching of science.

One sometimes hears it said that there is no one method of teaching science. This is probably true. Successful teachers generally realize that with changing goals and ideals come changing methods. There are some who contend that if a person possesses a comprehensive understanding of science and an intensified knowledge of one particular field that he is ready to teach science. The authors are not in agreement with this point of view. It is their belief that the beginning teacher of science is greatly strengthened and more likely to succeed if in addition to a sound knowledge of science he possesses the following:

(1) A philosophy of science teaching which will give reason and purpose to his teaching procedures.

(2) A psychology of science teaching which insures that he knows how children learn.

(3) An understanding of the major goals of science teaching.

(4) An understanding of scientific method and attitudes and definite techniques sufficient for inculcating them into the minds of his pupils.

(5) The ability to use modern techniques in measuring the results of his teaching.

(6) A comprehensive knowledge of the materials and devices which make science teaching more meaningful and more interesting to the learners.

The book is divided into three sections. Section one is

devoted to principles of science teaching. There has been a persistent tendency among science educators to place the outcomes of science teaching in four categories: (a) specific habits and motor skills; (b) knowledge, commonly referred to as facts, concepts, principles, laws or generalizations; (c) understanding and use of the scientific method; and (d) general patterns of behavior as ideals, interests, tastes, and attitudes, particularly scientific attitudes.

It is our purpose in this section to present information which will enable teachers to develop a working philosophy and a sound psychological basis for the achievement of the major goals of science teaching. Considerable attention is also given to modern practices in laboratory and demonstration work and to techniques useful in measuring the results of science instruction.

Section two is devoted to a treatment of visual and other sensory aids useful in teaching science. In recent years, science and invention have opened up great possibilities in the development of concrete visual materials and devices for science teachers. Inventions and discoveries in the fields of photography and photo-engraving, microscopes, motion pictures, stereographs and stereoscopes, graphs, and models are all contributing toward making science instruction more meaningful to the learners. However, it does not necessarily follow that because a teacher uses the various visual aids that he is doing good teaching. Practically every visual aid has both advantages and limitations. Information is given in this section which should enable science teachers to evaluate various sensory aids and to determine their degree of usefulness in varying classroom situations.

Section three presents a compilation of sources of materials useful in teaching science. Enough information is given about each one to enable a teacher to determine quickly whether the aid in question will fit into his teaching plans. Each one of the visual aids was evaluated by one or more of the authors. Since materials of this type are sometimes discontinued it cannot be guaranteed that every one of them will be available

by the time this book is distributed. They were all available, however, at the time the manuscript was prepared.

During the course of preparing this work it was necessary for the authors to avail themselves of the contributions to science education of a large number of people.

We acknowledge our indebtedness to all who have done pioneering work in laying a foundation for the development of a science of science teaching. The following persons deserve special thanks for examining and criticizing parts of the manuscript: Dr. Daniel Wolford LaRue of the East Stroudsburg State Teachers College, Dr. Ralph Tyler of the University of Chicago, Dr. J. Lloyd Bohn of Temple University, Louis Heil of the Evaluation Staff of the Progressive Education Association, Benjamin Gruenberg of New York City, Gaylord C. Montgomery, and Ben Wells of the John Burroughs School.

We are also very grateful to the individuals and firms who furnished illustrations for the second section of the book. Specific acknowledgment is included with each illustration.

THE AUTHORS

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Section I

Principles of Science Teaching

Chapter I

A Philosophy of Science Teaching

MANY books have a plot or theme which runs as a thread through their pages. It is the purpose of the first chapter of this book to set forth simply and directly a point of view in science education which the remaining chapters will develop and illuminate. It may be that not all who read these pages will agree entirely with this point of view. Perhaps that is best, for it is out of the discussion of differences in point of view that real progress usually emerges. While we may differ in our philosophies of science teaching, we are all concerned with the progress of science education.

In one respect it is unwise to set down in such a book as this a point of view or philosophy which then becomes fixed, and no longer possesses elasticity and adaptability. A philosophy of science teaching at its best should be a guide, flexible enough to include the best which has come from the past and yet mindful of the new developments in the field. True progress in any field can come only by a gradual growth wherein the new is tempered with the best from the past, to produce a forward-looking present.

In the final analysis a point of view as a philosophy in any field is a personal thing molded and shaped by individual experiences and backgrounds. It is not the purpose of the authors to set up this statement as the one philosophy of science teaching, but it is rather their hope that it may serve, perhaps as a guide, perhaps as a stimulus for some who are attempting to formulate a personal point of view in this area. The values of a personal philosophy of teaching are far-reaching. It enables one to weave together the many diverse threads of experience and association into a meaningful pattern of relationships.

The youth of today must adjust themselves to a much more complex world than existed a generation or even two decades

ago. We are living in a fast-moving age in which strong forces are tending to produce rapid changes. These boys and girls have become so used to the phrase, "we live in an age of science," that they are prone to take it as a matter of course and never stop to reflect on the premises which lie back of such a generalization.

An individual in this present-day world is not unlike a cork on a turbulent ocean being buffeted about by the ever-changing forces of the winds and tides. The traditions and customs of our social order drive him now with and now against the forces of a rapidly changing physical environment brought about by advances of a technological nature. In this chaotic scene the individual is confronted with the urge to resolve it for himself and the immediate need to adjust to its ever-changing patterns.

One need consider only a small sampling of the factors at work in present-day living to secure convincing evidence that we are living in an age of rapid change and that science is playing a predominate part in bringing these changes about. The radios of a decade ago are now obsolete. Travel by air has increased rapidly. Injury and death from automobile accidents are mounting year by year. Frequent devastating floods in recent years and the recurrence of severe dust storms in certain parts of the country have made conservation a national problem. Unemployment is in part due to the introduction of machines which replace man power. Many other immediate social problems could be cited, all of which have their origins deeply rooted in science or technology. It is these forces and their ramifications that the boys and girls of this age must understand if they would live most effectively.

If one may prophesy, judging by the trends as evidenced in the past few decades, it seems reasonable to predict that forces of science, technology, and social change will play an increasingly important role in the lives of individuals. Thus more and more they will be confronted with problems which have causes arising in the area of science.

The causal role of science as a basic factor in many of our

present-day social problems makes it essential for the science teacher to look for the ultimate goals of his instruction beyond the narrow confines of pure science to the social implications that result from technological causes. It is no longer sufficient to regard the end of educational procedures as preparing for some dimly visioned future. The young people whom we teach are experiencing life on every hand and must be conditioned to adjust to its forces and to solve the problems which are at their maturity levels.

The first reaction that one naturally gives to such social implications as those mentioned above is that they are problems of large scope and are relatively remote from the lives of boys and girls. However, study reveals this to be a false assumption, for it is difficult to find a single element of social change which does not affect the immediate lives of boys and girls, creating real problems for them which they must solve. Thus science teachers are faced with the necessity of becoming sensitive to these problems of boys and girls and so setting the stage for learning that science materials will make a contribution in the solution of their problems.

Earlier in this chapter it was pointed out that the teacher must formulate a philosophy of teaching to suit his own conditions and needs, but he must guard against the possibility of this philosophy becoming rigid and fixed. It should be flexible, adaptable, and developing in its nature. Just as the scientist always holds his hypotheses subject to modification with the introduction of new evidence, so must the philosophy of a teacher develop and shape itself to the conditions and factors of social change.

The problems which confront boys and girls today are complex. This is true not alone because the forces bringing about social and economic change are complex, but also because the adjustment of an individual to each problem or situation is different. No two individuals are set up with the same hereditary backgrounds, the same emotional patterns, the same needs, or the same sensory equipment to receive impressions from a given situation which confronts them. This means

that when a group of boys and girls are faced with the same situation demanding adjustment from all of them, we may expect many different types of behavior from the individuals in the group. This creates an extremely difficult situation from the standpoint of teaching, for one implication is that for maximum effectiveness we should have to make individual case studies in each adjustment situation. This of course would be inefficient with our present educational setup, and with most teachers untrained to make such studies.

The nearest approach we can hope to make at present toward helping students to adjust themselves to the situations confronting them is to study the broad picture of modern life and attempt to see the larger aspects wherein most of the boys and girls will find the situations to which they must adjust. It will, moreover, be necessary to study carefully the behavior patterns of boys and girls of school age to see if any central tendencies regarding needs can be ascertained. Then from these broad studies it may be possible to block out certain general needs of young people in present-day society, to the end that science materials and learning experiences may be redirected to bring about a more effective adjustment to the problems growing out of these needs.

Reference has been made to the role which science and technology have played as antecedents for some of the social and economic conditions confronting us in modern life. Involved in this fundamental relationship lies an obligation for science to share in making more effective the adjustments of boys and girls to these conditions which it in part has created.

A study of the aspects of present-day living which seem to have science antecedents or implications, and a study of the needs of boys and girls as evidenced by their behavior patterns would seem to reveal that there are many focal points where science can aid in the adjustment of individuals. These focal points are in many ways characteristic of individuals for, as has been pointed out, no two individuals bring the same equipment to a single situation demanding adjustment. Regardless of the complexity of the problem, there seem to be

certain cleavages which make possible a description of the contributions science is peculiarly fitted to make in order to achieve a more effective adjustment of the individual.

In attempting to make such a classification of these functions it is the purpose here to suggest only one point of view. Other classifications, equally as useful, have been made. It should not be construed that these categories are hard and fast, but rather that they are flexible and probably overlap at many points.

I. *SUGGESTED CLASSIFICATION OF THE FUNCTIONS OF SCIENCE IN THE ADJUSTMENT OF INDIVIDUALS.*

(1) Science can contribute a fund of interpretive understandings to aid the adjustment of individuals.
(2) Science can contribute a fund of appreciations to aid the adjustment of individuals.
(3) Science can contribute a group of attitudes or mind-sets to aid the adjustment of individuals.
(4) Science can contribute a method of attack on problems to aid the adjustment of individuals.

These will be discussed in detail, as the Major Goals of Science Teaching, in Chapter II.

The movement toward the socializing of science instruction is not new. The *Report of the Committee on the Reorganization of Science in the Secondary School,*[1] published in 1920, attempted to show wherein the materials of specialized science could be utilized to better achieve the larger social goals which had been set up as the well-known seven "cardinal principles." The implications of this report have been far-reaching in their influence on science teaching in this country as is seen by a survey made by Beauchamp in 1932.[2]

In 1932 *The Thirty-first Yearbook of the National Society for the Study of Education* [3] was devoted in part to a Program for

[1] Bulletin 26, 1920, United States Bureau of Education. *Reorganization of Science in Secondary Schools.*

[2] Bulletin No. 17—Monograph No. 22, 1932, United States Bureau of Education, "Instruction in Science."

[3] *The Thirty-first Yearbook of the National Society for the Study of Education,* Part I, "A Program for Teaching Science," Public School Publishing Co., Bloomington, Ill., 1932.

Teaching Science. Parts of this report pointed out the need for teaching science in such a way as to make for a more effective adjustment of the individual to the world about him.

More recently the Science Committee of the Commission on the Secondary School Curriculum of the Progressive Education Association has published a final report [1] of its position on science teaching.

All of these major reports represent a definite and steady trend from the subject-centered curriculum in science, dominant at the close of the last century, to the social-centered curriculum in science just emerging.

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[1] *A Progress Report—Science in General Education*, Commission on the Secondary School Curriculum of the Progressive Education Association, New York, 1937.

Chapter II

The Major Goals of Science Teaching and Their Attainment

SCIENCE has played an important part in bringing about many of our social problems and no doubt will continue to influence social trends for some time to come. Therefore science is fundamentally obligated to contribute to the education of young people those values peculiar to it in order that their adjustment to the life about them may be effective and complete. In defining the functions of science in the adjustment of the individual, we have set forth what would seem to be the major goals of science teaching. This chapter will be devoted to an enlargement of these functions; namely:

(1) A fund of interpretive understandings.
(2) A fund of appreciations.
(3) A group of attitudes or mind-sets.
(4) A method of attack on problems.

I. *A FUND OF INTERPRETIVE UNDERSTANDINGS.*

The Thirty-first Yearbook of the National Society for the Study of Education [1] sets forth a plan for organizing the materials for science instruction around a group of basic concepts or understandings which had been derived from the writings of pure scientists. This scheme of organization for science materials was a distinct contribution to the field, but had the limitation of viewing science instruction only from the angle of pure science, without much concern for the values of science materials as they may help the individual to interpret and adjust himself to the problems of modern living which have technological implications.

A few examples will serve to show what is meant by a pure science generalization:

[1] *The Thirty-first Yearbook of the National Society for the Study of Education,* Part I, "A Program for Science Teaching," Public School Publishing Company, Bloomington, Illinois, 1932.

(1) Space is vast. 104.
(2) There are ninety-two elements.
(3) The age of the earth is very great.

Somewhat in contrast with this sort of generalization or understanding is the meaning which the authors attach to interpretive generalization. The meaning here is rather a statement of a science concept, understanding, or generalization which has some social implication or connotation or "which results in significant changes in the individual's behavior" as it is so well expressed in the *Progress Report* of the Science Committee of the Commission on the Secondary School Curriculum of the Progressive Education Association.[1] An interpretive generalization in this sense would be the understanding of a science concept which might aid the individual in making an adjustment to some problem or situation which confronts him. A few examples of interpretive generalizations will serve to make this matter of definition clearer. These illustrations have been selected from the *Progress Report* of the Science Committee of the Commission on the Secondary School Curriculum.[2]

INTERPRETIVE GENERALIZATION.

(1) Man is limited and influenced by the environment in his use of energy and materials.
(2) Natural energy can be controlled and used for the purposes of economic life.
(3) The production of the various kinds of goods needed by modern society depends upon the use and control of a wide variety of materials.
(4) Conservation of material resources is a responsibility of modern society.

From this point of view it would seem that when pure science concepts become the major objectives then the end sought is the understanding of content, while in the case of

[1] *Progress Report—Science in General Education,* The Science Committee of the Commission on the Secondary School Curriculum of the Progressive Education Association.

[2] *Ibid.*

the interpretive generalization the science principles are to be learned and applied in social or economic settings. Understanding of a pure science concept may have value in certain specialized adjustments which a limited group of young people will make; however, when interpretive generalizations are the outcomes sought, the needs of a larger group of students will be met.)

The importance of interpretive generalizations for the adjustment of individuals is not remote, but becomes very real and immediate when one considers the focal points in the everyday experience of boys and girls where science situations and their social implications merge to create real problems. A few of these will illustrate the point. Each of the following, and probably others, are general areas of adjustment under which groups of interpretive generalizations or understandings might be stated. Science instruction might then be directed toward the achievement of these generalizations.

1. *Health.* There is no more important aspect of present-day living than good health.

A health problem may be an immediately personal one to an individual, as in the case of diet, or a health problem may be a community concern, such as sewage disposal or a pure water supply. Again a health problem might be national in scope, as in the case of an adequate Pure Food and Drug Bill to be passed by Congress. Regardless of the scope of these health problems we find the science materials inextricably bound up with social situations.

2. *Safety.* The problems of safety with respect to home, school, community, or nation are of extreme importance. It is believed that proper education can go a long way toward lowering the number of accidents and deaths from accidental causes. Science can contribute much to this education, for many of the causes of accidents have science relationships such as the prevention of fires, the automobile, electric shock, or drownings. Thus safety in all its many aspects becomes another focal point in contemporary living where the ad-

vances of science have led to social effects which young people must understand and to which they must adjust.

3. *Conservation.* This national problem has been brought forcibly to the front during the past few years by the recurrence of floods and dust storms in certain sections of the country. If we ever hope to achieve really widespread concern for, and action on, the problems of conservation, the topic must be introduced more frequently in our schools. At present we are doing little with it in science, and yet the basic reasons and needs for conservation find their causes in science meanings such as the origin and nature of soils, erosion and its control, forests and floods, conservation of water power, irrigation, conservation of natural resources, and agencies of conservation. Each of these has science-social significance for the individual, the community, and the nation. Thus conservation becomes a problem in modern living to which many people must adjust. Complete and effective adjustment can come about only as the individual has built meanings for the specific science understandings in their social settings.

4. *Consumership.* Every individual is a potential consumer of goods and materials and should have, as a result of education, a stock of functional understandings to bring to bear on the problems which will confront him in this aspect of living. In this area probably more than in any other do we find an involved interplay between the science understandings and the social implications. Most goods and materials at some point in their production, processing, or distribution have had to do with some phase of science. To be an intelligent consumer and adjust effectively to the myriad problems that arise at this focal point, the individual should have a background of science understandings. Thus consumership as an area of adjustment or focal point and its attendant problems might form the basis of a group of interpretive generalizations toward which science instruction might be directed.

These four illustrations have been dealt with in some detail to show what is meant by areas of adjustment and generaliza-

tions as contrasted with pure science generalizations. These are only a portion of the areas of adjustment of focal points in modern living where science and its social implications merge. Others which might be mentioned are: Adaptation, Materials, Production and Control of Energy, Interdependence, Time and Change, Improvement of Life, etc.

If a selected group of interpretive generalizations is to become one of the principle outcomes sought as a result of science instruction, then they must be more than merely stated goals or objectives. They must find their way into the organization of science courses so that they are just as directly the objectives of teaching as is the mastery of facts or principles. This naturally raises the question of the means of selecting the interpretive generalizations and the organization of the materials which will build meaning and understanding for them.

Pieper,[1] in *The Thirty-first Yearbook of the National Society for the Study of Education*, has suggested a useful list of criteria to be used in the selection of adjustments for the junior high school. With only slight modification these are applicable as criteria for selecting interpretive generalizations. These criteria are as follows:

"When in each case all other things are considered equal, criteria should be applied that will assure that those adjustments selected are:

(1) Universal in their application to life needs.
(2) In accord with the findings of science.
(3) In harmony with the best interests of society.
(4) Crucial in individual or social life.
(5) Conducive to the desire to make further worth-while adjustments.
(6) Of the proper order of difficulty.
(7) Highly satisfactory to the individual without giving harm to others or to himself.
(8) Desired by the pupils.
(9) Identifiable in their attainment.
(10) Essential to the making of other desirable adjustments."

[1] *Op. cit.*

The [1] Science Committee of the Commission on the Secondary School Curriculum of the Progressive Education Association proposes a useful set of guiding principles for the formulation of these understandings or generalizations:

"(1) Understandings and inquiries should be stated as working ideas used by the student in determining his behavior.

"(2) Understandings and inquiries should deal, in the main, with interpretive rather than pure science generalizations. The interpretive understanding applies the results of science to the elucidation of problems which are of wide and rather common human concern, while the pure science understanding applies the results of science.

"(3) The understanding or inquiry should be stated clearly and concisely so as to convey a 'whole idea' to the teacher who is engaged in developing suitable learning activities. In general, the statement should be complete in a single sentence.

"(4) The level of generality upon which these understandings are formulated will depend upon the use to be made of it in teaching and learning situations. The most comprehensive understandings should be the result of the reconstruction of experiences over a period of years. Such statements may have subordinated to them less comprehensive understandings which indicate content more specifically.

"(5) The understanding should be so formulated as to avoid indoctrination or finality in interpretation. The purpose of this discussion is not to formulate a body of interpretive understandings, but rather to propose the focal points around which these generalizations may be stated."

It is probably unwise to go farther than this, since the nature and comprehensiveness of the understandings will vary, not only with the local situation, but with the level of maturity upon which they are developed. Later in the chapter the organization of materials and learning experiences to reach these generalizations will be discussed at length.

II. *A FUND OF APPRECIATIONS.*

Wheeler and Perkins [2] in their book *Principles of Mental Development* say, "The intelligence which education is calcu-

[1] *Op. cit.*

[2] Wheeler and Perkins, *Principles of Mental Development*, Chapter I, Thomas Y. Crowell, 1936.

lated to develop will not grow when uprooted from the background of feeling from which it springs."

Adjustments to the situations encountered in modern living are not made on the basis of cold factual applications alone but also with feeling and emotion. The whole situation is a complex of feeling, attitudes, and understandings. It would seem then that a background of appreciations which are peculiar to science should become one of the desired outcomes of this area.

The emerging of science as a body of tested laws and principles has been intimately bound up with stories of romance, privation, and adventure. These should become a portion of the cultural background of every boy and girl. In modern living he is called upon to use the products of science and invention. His intelligent adjustment to the problems growing out of this use will depend, in part, upon the extent to which he appreciates the background of their development; such as the story of Louis Pasteur and his services to humanity; the persecutions of Galileo in the name of science; Edison, and the discovery of the electric light. These and others should be in the stock of appreciations which many boys and girls will need for complete adjustment.

Not only is the development of science knowledge filled with fascinating historical and biographical incidents, but also with appreciations which give perspective to life and character. The tremendousness of space; the vastness of the sweep of geologic time; the law and order of the universe; confidence in the method of the scientist. These and others which might be listed give ample justification for the inclusion of a fund of appreciations as one of the major goals of science teaching.

Later in this chapter the attainment of appreciations as outcomes will be discussed.

III. *A GROUP OF ATTITUDES OR MIND-SETS.*

Science teaching has long concerned itself chiefly with the mastery of laws, facts, and principles to the neglect of certain

of the less tangible, but none the less desirable, outcomes, such as attitudes of mind. There has been a belief that if the former were done thoroughly the growth in scientific attitudes would result concomitantly.

Within the last few years science teachers as well as teachers in other areas have become aware of the fact that if attitudes are to result from the study of science or any other subject, they must be sought just as deliberately in the classroom as are the mastery of laws or principles.

Attitudes have been defined in many ways. Here the accepted definition is—a mental motor set of the individual which is characterized by predisposition toward objects, persons, or events and a tendency to act. Thus there is hardly a science situation demanding adjustment which in one way or another would not involve an attitude of mind. Since they are so essential, science teaching should seek to contribute whatever it can to the attainment of such a fund of desirable attitudes on the part of the individual.

While it is probable that science is better fitted by the very nature of its materials and methods to foster the development of certain attitudes, it will be found that they also can be developed through the work in mathematics, social studies, foreign languages, and English. This makes it desirable to see the attainment of these outcomes as a whole-school responsibility and thus aim at them from many different angles.

A suggested list of attitudes and safeguards will be found in a later chapter.

IV. *A METHOD OF ATTACK ON PROBLEMS.*

The methods used by the scientist in his efforts to discover truth have long been looked upon as effective in the solution of problems of a nonscientific nature. The method has been studied and analyzed and its steps are well understood. Science is peculiarly suited to the training of young people in the skills and habits basic to this method.

The scientific method, as a desirable outcome of science teaching is not new. For one may read in the preface of al-

most any textbook, or the objectives of any course of study in the field, that scientific thinking should result from the study of the book or the following of the course of study. There is little evidence at present to show the degree to which science instruction in the past has achieved this goal, but judging by the reactions of the average high-school graduate, it is safe to conclude that it has not been achieved to any great degree.

Such a condition has probably resulted because teachers have not been aware of problem-solving abilities as goals to be taught for, or because they have not understood the technique of classroom instruction which may lead to their accomplishments.

Training in the abilities involved in problem solving becomes more important when one considers the fact that most of the situations in present-day living crop up in the pattern of a problem or a perplexity. If through his learning experiences in school the individual has learned how to recognize, attack, and solve problems, it is likely that he will be able to adjust more efficiently than if he had not had the training.

There is still considerable difference of opinion concerning the extent to which skills and habits acquired in one context may be transferred to a new situation. This would seem to point out that, as in the case of developing attitudes, training in the techniques of problem solving should be a school-wide objective. Thus experienced, an individual would have a greater chance to attack a novel situation which had some degree of similarity to one or more of the contexts in which the problem-solving skills and techniques had been learned.

There is considerable evidence available to show that content as now taught in several of the sciences is not particularly functional when new situations demanding the application of learned principles are presented. Also there is another body of evidence that seems to reveal that content as now taught is not retained for any length of time and that the curve of forgetting falls off very sharply after a lapse of a few months.

On the other hand Tyler[1] has shown through certain of his studies that content learned in reference to the solution of problems where problem-solving abilities are actively used in the process, is, instead of being forgotten, actually augmented with the passing of time.

As noted earlier in the chapter, it is quite probable that science and technology will continue to influence our changing society for some time to come. While we have no way of predicting the kind of adjustments that the young people of today will meet as adults of tomorrow, it is reasonable to assume that these will, in many cases, be problems which will have to be solved. Since we cannot teach specifically for these adjustments it would seem that the best safeguard for satisfying adjustment which we can now give these adults of tomorrow should be a method of attack which will enable them, at least in some degree, to cope with these problems.

Problem-solving abilities as major outcomes for science teaching can be achieved only when they are sought as desired behavior changes in students and when the learning activities in the classroom are so set that students are given recurrent training in the elements involved. They must be taught for as deliberately as are the mastery of facts and principles.

THE ORGANIZATION OF MATERIALS TO ACHIEVE THE MAJOR GOALS OF SCIENCE TEACHING

Earlier in this chapter attention has been directed to the major goals of science teaching, and now one type of organization of the materials and methods of instruction which may lead to these outcomes will be considered. There are no doubt other methods of organizations which, when applied, will give equally good results.

It has been suggested that there are many focal points in the adjustment of individuals to modern society where science and social implications merge. Some of these points of merging

[1] Tyler, Ralph W., *Constructing Achievement Tests*, Ohio State University, Columbus, Ohio.

have been suggested such as Health, Safety, Conservation, Adaptation, etc.

For purposes of functional outcomes each of these focal points may well become the basis of statement for a group of major interpretive generalizations to which the study of certain science materials may contribute meaning and understanding. These generalizations would then become the cores or themes about which appropriate content might be arranged to develop the meanings and understandings desired.

The scope of any single one of these interpretive generalizations would be very great and might conceivably spread over a number of years of science study. For example the adjustments concerned with health are not peculiar to any grade level, but range in complexity from the simple health problems of the Kindergarten youngster to the involved adjustments of a High-School student. Certain simple meanings related to health might be encountered in the Kindergarten and then recurrently on every grade level through the High School. Thus these generalizations would take on added meaning and enlargement from grade level to grade level with appropriate materials and learning experiences selected at each level.

In a similar manner each of the major interpretive generalizations derived from the areas of adjustment or focal points, might form a strand or a theme reaching as far down into the elementary school as possible and developing from grade level to grade level, through the senior high school. These themes as organizing centers would then provide vertical integration of science content from the first grade through the twelfth. With such themes as organizing centers it might be possible to make our science more effective and functional if individuals were called upon to use it in making adjustments at the focal points involved.

Not only would such a plan provide for rather complete understanding of the interpretive generalization at the end of a sequence, but at any given grade level it would make possible the utilization of materials for immediate adjustments

demanded at that level. For example if in the third grade an individual was confronted with the problem of adjusting to a contagious disease in his home, he might not understand all of the implications of quarantine, but he would probably be able to adjust properly because of his school associations with others who had been quarantined. A youngster playing with an electric train may not understand all of the energy transformations, but he will have had sufficient experience to know that if the track pulls apart his train will stop and can only be started once more when the track is connected.

Since the scope of any of the suggested areas of adjustment and consequently the derived interpretive generalizations is very great, for purposes of efficient learning they would be analyzed into subgeneralizations and these then further analyzed into simpler parts. For example the Health Area would naturally include much of the material that is now taught under the classification of Foods. This topic of Food might then form the theme for one of the subgeneralizations under Health. There are aspects of the Food theme which are real problems for even the youngster on the first-grade level and so on up through the various levels. Each major adjustment area such as Safety, Conservation, Consumership etc., would be analyzed until it reached problems of adjustment appropriate for any specific grade level. The solution of these problems would then build up meaning and understanding until they were approached sometime in adulthood.

The second major goal set for science teaching is a fund of appreciations. To achieve these the content must be learned in its relationship to the historical and biographical backgrounds in which it was evolved. This would imply that as a student collects evidence on any given problem some consideration and time should be given to the backgrounds of the content. Such a method will seem not only to make adjustments more successful and rich, but will link the content of science with the cultural heritage and backgrounds of the race. Also since every adjustment which individuals are called upon to make is colored to some extent by attitudes

and emotions these appreciations will provide feeling tones with which the individual may attack the problem involved in the particular adjustment.

The matter of achieving the outcomes of attitudes and methods of attack on problems will be best accomplished through the methods of learning used by the student. As the interpretive generalizations are analyzed into simpler and simpler elements, they finally come down to specific adjustment problems appropriate to a given grade level.

In attempting to solve these adjustment problems the learning experiences may be so set up in the classroom that the learner will be called upon not only to maintain the attitudes desired as outcomes, but to use the same methods as have been found effective by the scientist. By being thrown constantly against these problems and being called upon to use over and over again the skills and abilities desired as outcomes, the individual will develop them to the point where they will become habits of action with him. He will then be better able to utilize them in the solution of new and novel problems which may occur as adjustments he will have to make in the future.

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Chapter III

Psychology of Science Teaching

MANY science teachers live by faith to a remarkable degree. They prepare materials for their classes, meet their classes, describe, explain, and exhort with implicit faith that learning is the result.

It makes for clarity in science teaching when the teacher understands the major goals of science teaching and the methods useful in reaching these goals. It is our purpose in this chapter to present: (1) a brief analysis of the goals in learning science from the standpoint of psychology; (2) the factors which condition learning; and (3) those psychological principles which may be useful to science teachers in developing methods for reaching the goals in learning.

I. *GOALS IN LEARNING SCIENCE.*

a. The Acquisition of a Fund of Understandings. Specific information about subjects or events is acquired by reactions to stimuli which affect our sense organs and which give rise to sensations of sound, odor, etc. The pupil sees a flower and states that it is a blue flower. He sees an exhausted can crushed by the atmosphere and states that air exerts pressure. Psychologists call this *perception.* Facts are statements of the results of perception. In perception, the object or event is seen and interpreted in the light of experiences from the past.

Information may also be gained vicariously by reading or listening, if one has acquired the basic ideas needed to interpret what is read or heard.

Information lessons are of two kinds: either we observe something directly, as when we examine objects and specimens and watch demonstrations and experiments, or we translate somebody's message which comes to us as written or spoken words. "In either case" says LaRue,[1] "the first

[1] LaRue, D. W., *Educational Psychology,* Thomas Nelson and Sons, 1939, p. 189.

challenge of the lesson for information is to get its meanings: that is, to relate it to the mass of images, symbols, and feelings already in our heads; to *interpret* it. To perceive the outer world is to interpret sensations; a moving light in the sky turns out to be not a meteor but an airplane; that red on Johnny's finger is not blood from a cut, but a splotch of ink. The tadpole's tail disappears. What does that mean? What became of it? In the second type of information lesson we interpret symbols; words for the most part." What does it mean, for example, when the science textbook says "soil is formed by the forces of weathering and erosion?"

We also have many *concepts* to form. In science we have such words as fruit, seed, molecule, energy, work, erosion, mechanical advantage, and the like. Sometimes, for pupils, these concepts have but rough splotches of meaning whereas they should be as clear-cut as diamonds. Sometimes "weak" concepts are formed because of too much verbalism or too much "definitionism." It is possible for a pupil to give a perfect definition of a fruit and yet not be able to recognize samples of fruit.

Two of the chief causes of pupil failures in science courses are lack of concrete experiences with objects and events and the prevalence of hazy concepts. Pupils have difficulty in understanding a sentence such as this: "Fruit is the matured seed vessel and its contents, together with such accessory or external parts of the inflorescence as seems to be integral with them." When a teacher exhibited a potted fern before her class and asked what it was, one pupil said it was a "pot of green feathers." This pupil needed a trip to a greenhouse.

How Are Concepts or Generalizations Formed? They are formed by taking the task as a problem in thinking and then solving it. Let us see by means of a concrete case, how a concept may be formed. A student in a biology class is surprised when he hears his teacher speak of a pine cone, nuts, and watermelons as fruit. His curiosity is aroused. He asks, "What is a fruit?" He has formulated a problem. His teacher helps him to get facts by considering many samples of fruit, such as

apples and berries, cherries and plums, nuts, oranges, and tomatoes. As the study proceeds, the student notes various differences and sees that the "build" of the fruit is unessential. He then perceives that there is a quality or characteristic which is common to all of them: a fruit is the part of the plant which carries the seed. He has generalized and built up in his mind a concept of "fruit." This is the inductive process. The pupil may now, if the occasion arises, use the concept deductively. Is a potato a fruit? He examines a potato and finds that it contains no seeds. It is simply a modified stem.

Concepts transcend in meaning any particular percept. A percept refers to a specific situation; the concept is general and universal in its scope and reference. Science teachers should guide their students in distinguishing intellectually two kinds of qualities or characteristics; those peculiar to each situation, and those which it possesses in common with others of its kind or class. When the common element in a number of experiences has been recognized and abstracted from the multitude of accidental qualities, a concept has been formed; generalization has taken place. The end product may be a principle, a definition, or even a scientific law. Experiences thus generalized into concepts make possible transfer of knowledge and adaptability to new situations.

b. THE ACQUISITION OF A FUND OF APPRECIATIONS. Because of the rapidly growing body of scientific knowledge, there is great danger that in our science teaching we may uproot this knowledge completely from the background of feeling and experience from which it has sprung. In so doing, pupils may lose some of the educational values such as appreciations, social sensitivity, and attitudes which by many educators are considered just as important as the mastery of facts and principles of science.

The emergence of science as an area of knowledge is intimately bound up with thrilling stories of privation, persecution, romance, and adventure; for example, the life and work of Louis Pasteur, the suffering of Galileo in the name of science, the persistence of Edison which led eventually to the

invention of the incandescent lamp. Through the study of episodes in the history of science it is likely that boys and girls will gain a better appreciation of science and the role which scientists play in our complex society. Furthermore, boys and girls may also acquire a better understanding of the attitudes, emotions, and thinking which characterize the work of a scientist and a greater feeling of confidence in the scientific method. Science is also rich in possibilities for the development of appreciations which give breadth and perspective to life and character. It has been observed that narrow-mindedness and bigotry tend to diminish as people, through a study of science, learn to appreciate the vastness of space, the tremendous sweep of geologic time, and the orderliness in nature in which effects result from natural causes.

c. The Acquisition of Certain Attitudes or Mind-Sets. Science educators have long recognized that scientific attitudes are among the most important outcomes which should result from science teaching. Although some educators have considered scientific attitudes as by-products or concomitant forms of learning there has been a persistent and growing tendency to view these attitudes as equal to or superior to the knowledge objective of science instruction. Science teachers are becoming aware of the fact that if scientific attitudes are to develop from the study of science, they must be taught for directly and systematically in the same manner as we try to develop a mastery of the principles of science. There is now some objective evidence to support this belief. Peters [1] and his associates have made an extensive series of investigations on the relative efficacy of systematic versus incidental instruction in shaping and directing attitudes. The data of these investigations show that when attitudes are made the center of attention in the teaching situation greater gains result than when they are held in the margin of attention.

An extensive analysis of scientific attitudes and suggestions for their attainment are given in Chapter IV.

[1] Peters, C. C., "Some Techniques for the Quantitative Study of Values of Learnings," *Journal of Educational Sociology*, Vol. VII, No. 4, 1933, pp. 213–272.

d. A Method of Attack on Problems (Problem Solving). It seems no longer defensible to assume that mere mastery of facts and concepts of science will suffice to meet the needs of the child. It is emphasized in progressive practice that the experiences through which mastery and understanding are attained should contribute to growth in some of the educational values such as appreciations, social sensitivity, and skill in problem solving. With this new emphasis in education, the subject matter of science is not the end but the means to an end of providing experiences that will result in development in the child of careful and thorough habits of thinking. If this view is accepted it becomes exceedingly important that the science teacher be thoroughly familiar with the steps in the complete act of thought: (1) a perplexing situation; (2) definition of the problem; (3) collecting data relevant to the problem; (4) setting a hypothesis; and (5) testing the hypothesis. A more complete analysis of problem solving appears in the next chapter.

II. *THREE FACTORS WHICH CONDITION LEARNING.*

Learning is an active process. The learner is in interaction with his surroundings, being stimulated by and responding to his surroundings. Three factors are involved in the learning process:

a. The Psychological Factor: Motivation. Motivation is, in a very large degree, the very heart of the learning process. Interest is prerequisite to effort. Incentive, purpose, and drive set in motion the activities which result in learning. The science teacher should consistently devote much thought and energy to ways and means of developing and maintaining, in her students, interest and enthusiasm.

Motivation may be *intrinsic* or *extrinsic*. When the subject matter of science courses is made so meaningful to the student that the student is bound to his work by interest within activities themselves, the learning of science carries its own reward. Motivation, then, is intrinsic. The student engages in wholehearted, purposeful activity. This is the ideal in teaching.

For various reasons it is not always possible to maintain the ideal situation in which learning for its own reward is the motivating force. Most teachers find it necessary at times to resort to extrinsic forms of motivation. The following are some of the more common forms of extrinsic motivation:

1. *Rewards and Punishment.* Rewards are powerful incentives but they are questionable forms of motivation. Progressive educators believe that the satisfaction which comes from seeing a task well done is the best reward; whereas failure due to lack of effort carries with it its own natural form of punishment.

2. *Rivalry.* Some teachers encourage rivalry between individuals in a class and rivalry between groups. Rivalry is a powerful incentive but it is a dangerous form of motivation in that it tends to breed resentment and jealousies. Self-rivalry, in which the teacher encourages the pupils to compete with their own past records is a valuable type of motivation.

3. *Praise and Blame.* Some psychological investigations indicate that, regardless of age or sex, praise is a more effective incentive than blame or reproof.

4. *Knowledge of Progress.* Data from experimental psychology have established the fact that realization of progress on the part of the pupils tends to stimulate further effort. Frequent failure discourages pupils. Science courses should be adjusted to keep the lesson assignments within the mental capacities and interests of the pupils. The use of graphs and other records of progress which keep the pupils informed of the progress they are making tends to motivate the work.

b. THE PHYSIOLOGICAL FACTOR. It has been stated that knowledge is based on sense perception, and that sense perception is the foundation of all higher forms of knowledge. Learning, therefore, is dependent on the conditions of the senses and the general tone of the individual.

Defective sense organs retard learning. Investigation shows that visual defects are prevalent to the extent of thirty per cent in secondary schools. Defects of seeing are some-

times passed unnoticed for a long period of time. These defects may cause headaches, nausea, dizziness, and disinclination to study.

c. The Environmental Factor. Atmospheric and other conditions in the schoolroom influence learning. The best atmospheric conditions are 68° F., 50% relative humidity, and 45 cubic feet outside air per person a minute.

The psychological "atmosphere" (environment) has been shown to be more important, in some ways, than physical conditions in the schoolroom. A pupil's work may rise or fall because of the partner or associates he has in the laboratory.

III. *PRINCIPLES OF PSYCHOLOGY.*

Attention is now directed to those psychological principles which state the more fundamental conditions under which learning takes place.

a. Law of Readiness. This psychological principle has been formally stated as follows: "When a bond is ready to act, to act gives satisfaction; and not to act gives annoyance. When a bond which is not ready to act is made to act annoyance is caused." Probably the greatest problem a teacher has to face is that of securing a favorable attitude on the part of the pupils she teaches. Attention and mind-set are fundamental to learning. When a pupil is getting ready for his science hour, his state of mind is perhaps the most important factor in determining progress as well as success in work. When a pupil dislikes what he has to do his rate of progress is slow.

It is important that students of science get the right start. At the beginning of a science course the teacher should assign the work which is within the range and grasp of the pupils and then lead, gradually, to more difficult work. If children are to learn effectively they must have a favorable mind-set toward the teacher, the school, and the tasks assigned to them.

b. Law of Exercise. This principle may be stated as follows: Other things being equal "exercise strengthens, and lack of exercise weakens the bond between situation and re-

sponse." That "practice makes perfect" is the popular version of this principle. However it is necessary to state at this point that sheer repetition does not necessarily result in strengthening of connections. It is now believed by psychologists that repeated occurrences of a situation do not in themselves assure learning. Practice makes for continued improvement if and when attention and observation go along with practice. When attention and observation are lacking, repetition is generally of no avail.

c. LAW OF EFFECT. This law may be briefly stated as follows: "Satisfying results strengthen, and discomfort weakens, the bond between situations and response." In a man (and lower animals) profitless acts gradually become eliminated. Here again it must be mentioned that this principle also has been severely criticized by both behaviorists and gestaltists. It seems to be a fact that people may remember experiences which are painful to remember and this condition is not adequately explained in the law of effect.

The psychological principles of readiness, exercise, and effect indicate that there is a close relationship between interest, attention, and effort. The teacher must stimulate interest. The pupil must be prepared for the work he is to undertake. The pupil must be in a state of readiness to act along desirable lines. When the pupils are in a state of readiness to act and the act is accompanied by satisfaction, learning results and habits of thinking and acting are formed as a result of exercise and study.

PROBLEM SOLVING

A major emphasis of progressive education is that school subjects should be centered around real, significant problems, and that pupils should be taught how to solve problems. This view is a reaction against the traditional conception of learning as the accumulation of facts or items of information. "Learning," says Dewey, "is a learning to think; and, upon its intellectual side, education is the formation of careful and thorough habits of thinking."

Pupils enjoy solving problems when they see some significance to them. With proper mind-set they are able to surmount many difficulties, and, in addition to learning facts, they are building habits, skills, attitudes, and appreciations. This is the progressive point of view of education and learning.

Through problem solving we attempt to formulate a *pattern of behavior or a habit of action* which will help develop in the pupil objectivity of thought, clarity of method, and an unprejudiced basis for the conclusions to his problems.

While problem solving is the least understood form of behavior, it must be thoroughly understood by the science teacher if he is to guide pupils successfully in employing the techniques involved. We present, in the next chapter, a fairly comprehensive analysis of the process which may help the science teacher in guiding the pupils in their attempts to solve problems.

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Chapter IV

Methods of Teaching Science

THE problem of transfer of training has long been discussed in education. From a consideration of the experimental evidence in the field it would seem that the existence of transfer may no longer be doubted, but as to the amount, and the methods of achieving it, there is much disagreement. There seems to be considerable agreement, however, on the point that if transfer values are to be effected they must be taught for directly and not left to chance.

Transfer is a problem of methods at least in so far as its attainment is concerned. This is especially true in the achievement of the less tangible goals of science teaching such as attitudes, appreciations, and methods of thinking. If such goals are to become a part of the outcomes sought by science teachers, then they must not only be worked for directly in the classroom, but worked for in such a way as to enhance the transfer from the learning situation to other life problems.

CONVENTIONAL METHODS OF TEACHING SCIENCE.

Since the inception of science in the curriculum of the American high school one of the principal outcomes sought in learning has been the mastery of content. In the early high schools the learning was directed primarily to the mastery of facts. In recent years there has been an increasing tendency to direct learning in science toward its principles and broader generalizations. These trends are encouraging as they lead to a kind of learning which makes content more useful for the student as he faces problems of adjustment in everyday living.

Over the period in which science has been taught in the schools, several methods of instruction have been evolved either by trial and error or by careful experiment. Most of these methods have proved effective in mastering content. It is not to be assumed from this discussion that these methods

have failed to produce other essential outcomes, but it is true that the chief end sought has been a knowledge of facts and principles. The following discussion will review the advantages and disadvantages of some of the more widely accepted of these techniques.

The Lecture Method. It has long been recognized that teachers usually teach as they were taught. This tendency introduced the lecture method into the secondary school at an early date. For many years this was practically the only method of teaching science. Later, the lecture plan was modified to include the catechismic plan of recitation. Some of the early science books used in this country were written in a conversational style with the teacher asking a question and a pupil's answer following.

In the use of the lecture method the teacher develops a topic in science more or less from a logical organization. It is now very common when this method is used to supplement the lecture with demonstrations and visual aids. It is also a common practice today to have pupils participate in the lecture either by giving part of it or by doing experiments and demonstrations from the demonstration table.

The chief advantage of the lecture method is that it provides an efficient means of covering subject matter and more or less insures that the pupils will receive the material in a concise and logically organized manner. The greatest disadvantage is that the lecturer is usually the only active participant in the process, while the student is a passive recipient of information. In such a situation little responsibility for learning may be assumed by the pupil.

It should not be inferred from this discussion that the lecture method is essentially obsolete. There are many places in modern teaching where the lecture method may be used to advantage, such as in opening up a new unit for study or in summarizing principles at the close of a unit. It may also be used to advantage at many places for giving information bearing on the solution of problems or where for economy of time it is desirable to cover a certain area rapidly.

The Demonstration and Laboratory Methods. Chapter V of this book is devoted to a consideration of the techniques of these methods and therefore only a few important aspects of each will be considered here. Although these methods have frequently been separated in the literature of the past fifteen years, it seems wise to consider them together. Basically their function in teaching is the same. They are used as one means of securing information on a problem. In the past many educational experiments have been conducted to test which is the better of these methods in learning. Some consideration will reveal that as a general procedure neither is better. Each has its peculiar function in teaching, and the one which best serves a particular need should be selected.

The essential difference between the two methods lies in an often neglected realization that the demonstration is a device for illustration or application, while the experiment is a situation where elements are varied and controlled under various conditions. The demonstration may be used without much thought of control or variable factors, while these are the very essence of true experiment. The reader is here referred to Chapter V for a fuller discussion of these very important devices of instruction.

The Textbook Method. From the earliest period of science teaching in America the textbook has been an essential aid to learning. It is probably true that even today there are many places where the textbook is the course in science and where learning consists largely of reading the text and reciting its contents back to the teacher. In spite of the recognized abuses of the textbook method, there is no doubt but that it will continue to be an important adjunct to learning in science classes for many years to come.

Properly used the textbook may become a very important part of a course in science. When a single basal text is the only reference source, there is, of course, the danger that the pupils will come to think of the text as the only source of material and will thus have a distorted conception of its true value.

In many places sets of textbooks in the various science subjects are being provided. Rather than following a single text slavishly, many teachers are encouraging pupils to seek widely in several sources for the information that will help them solve their problems. This plan makes for better learning habits on the part of the pupil.

In recent years there have appeared on the market in the various sciences several texts which are based on problems. In these books many activities are suggested for aiding in the solution of the problems and usually references are given to other books dealing with the same problem. In this way a single basic text may be used to supply the pattern of development and other texts and references used in a supplementary way. In Chapter VI further consideration is given to the problem of securing information from books.

The Individual Method. Under the impetus of the measurement movement educators in general have become conscious of individual differences and have sought ways of providing for these in the classroom. Science teachers along with others have been active in devising schemes which would permit a student to progress through the work at his own rate. In most of these schemes the pupil has assumed the responsibility for his own learning, and this is a laudable point. It is, however, equally true that in many such plans the burden of administration has so increased that the teacher has become a mere checking clerk and bookkeeper. It should also be pointed out that when the individual scheme is used in the extreme, many socializing values of discussion and group work are lost.

Recently the extreme individual plan has been modified in most schools and the trend now seems to be to start a group together on a given unit and then permit them to spread on the basis of their working rates through the unit. Those who complete the work first are encouraged to do supplementary work. When the majority of pupils have completed the work of the unit, the entire class is assembled for discussion and student reports. As variations of the individual method, the

Dalton Plan, the Contract Plan, and the Project Method should be mentioned.

The Small Group Plan. In this plan of teaching the teacher opens up a new area of investigation, and the class then organizes into small groups to investigate the various problems which have been defined. Each group selects a group leader who becomes responsible to the teacher for the work of the group. The various groups then carry on whatever activities seem valuable for the solution of the problem at hand. From time to time the class is assembled by the teacher for general instructions or for hearing progress reports from the various groups. In the use of this plan, basic readings on the entire unit are generally required of all pupils. At the close of the unit the class assembles to hear the group reports, see important demonstrations, moving pictures, slides, etc., and to take part in discussion and organization of the materials.

The Development Plan. In recent years there has been an increasing tendency in many schools to have the students share in setting the objectives of the course as well as in planning the ways and means by which problems will be solved. In such a plan the teacher helps the pupils define their problems, guides them in securing, organizing, and interpreting data, setting hypotheses, and reaching generalizations. In such a plan the subject matter usually becomes the means to the end of solving problems and many opportunities are presented for instructing the pupils in good techniques of problem solving. The latter part of this chapter is devoted to a general consideration of various aspects of this method.

Recent Trends in Method. In many places new plans of curriculum organization are being tried which alter teaching methods essentially. Among these schemes are the correlated curriculum and the integrated or core curriculum.

In the correlation scheme there is an attempt to teach related subjects in such a way as to make possible the consideration of various aspects of a unit or topic in several classes at the same time. For example, a class may be studying Community Health in Social Studies while at the same time Com-

munity Sanitation and Water Supply will be under consideration in the Science Class. This plan seeks to better orient the pupil without breaking down subject matter lines.

With the integration plan time is provided in the program for a class to meet for at least two consecutive periods.

Several teachers are made available, and a topic is investigated without reference to specialized content areas. When the direction of the work falls in the social area, the social studies teacher directs the work and when a science problem is encountered the science teacher takes over. In some places the work in English, music, art, and other subjects grows out of the integrated materials.

In both the correlated and integrated schemes the great danger is that integration will be achieved only in the paper outlines of the course. True integration is achieved only in the thinking of the individual.

PROBLEM-SOLVING TECHNIQUES.

Setting the Problem. Children learn problem-solving techniques by solving problems which are both interesting and worth-while for them. If students are to have genuine interest in the solution of problems they should have some opportunity to share in the stating of the problems within a given area of adjustment and in planning their solution. The setting of the problems for study over a given period is very vital to the success of the learning and should therefore be planned carefully by the teacher. A coöperative approach may be used in which the teacher opens up the field for investigation, draws upon the experiences of pupils to suggest places where problems might exist, and then encourages them to state the problems in their own words.

Another method for setting problems may be used either with the one suggested above or independently. In this procedure the teacher does demonstrations, cites experiences, etc., in such a way as to raise questions and problems which are then stated by the students.

While problems are being set there is an excellent oppor-

tunity for the teacher to bring out certain characteristics of a good problem such as:

(1) The problem should be at or near the maturity level of the pupil.
(2) The problem should be stated clearly and concisely.
(3) The problem should not be too broad and inclusive.
(4) The problem should be properly delimited.
(5) The problem should in general be possible of solution with materials at hand.
(6) The problem should be worth while for the learner.
(7) The problem should be a part of an enlarging understanding.

Students should be taught to state problems in clear concise English. This is an excellent opportunity for the science teacher to aid in developing good expression skills. Students may be asked to write down their statement of problems. These may be read in class and critically discussed in the light of some such criteria as are suggested above.

This preliminary period of selecting and stating problems is an excellent time for the teacher to develop a greater sensitivity to problems in students. This is a difficult thing to develop, but may be aided by encouraging students to use their senses in getting impressions; to be analytical of experiences; to be questioning readers; to think about things and experiences in their environment.

After problems have been selected and stated, it is essential that time be spent in suggesting methods of solution, sources of information, etc. The next step then is to collect data on the problems.

Collecting Information Bearing on the Solution of a Problem. One of the most important steps in the solution of a problem is that of collecting data or evidence. The following analysis has been made to suggest certain of the basic skills and abilities involved.

(1) Ability to use the facilities of the library.
  (a) Card catalogues.
  (b) Periodical guides.
  (c) Reference books.
  (d) Classification systems.

(2) Ability to use books effectively.
  (a) Contents and chapter headings.
  (b) Indexes, appendices, glossaries, annotations.
  (c) Bibliographies.
(3) Ability to secure exact information from books.
  (a) Recognition of the sentence as the unit of thought.
  (b) Recognition of the central idea.
  (c) Acquiring a vocabulary.
  (d) Restating an idea.
  (e) Improving reading ability.
(4) Ability to secure first-hand information by experiments.
  (a) Acute observation.
  (b) Recognizing experimental factors.
  (c) Recognizing constant or control factors.
  (d) Resourcefulness in suggesting experimental procedures for variables and controls.
  (e) Manipulation of materials and equipment.
(5) Ability to secure information through interviews and conferences.
(6) Ability to secure information through visual aids.

Many of these important skills of problem solving may be taught during the period in which the student is collecting information on a problem. If he is to work effectively he must know how to use the library efficiently. At this point it may be wise to call on the librarian to give specific instruction in the use of card catalogues, periodical guides, classification systems, and general reference works. Also the student will need to use books efficiently. The science teacher may well give instruction in the proper use of tables of contents, chapter headings, chapter summaries, indexes, appendices, glossaries, bibliographies, and annotations. Pupils should learn early to be questioning about books as reliable sources of information. They should be encouraged to find out who the author is and to look for publication dates to check on the up-to-dateness of information.

Studies have revealed [1] that the learning of the technical

[1] Powers, S. R., "The Vocabularies of High School Science Text Books," *Teachers College Record*, January, 1925.
Powers, S. R., "A Vocabulary of Scientific Terms for High School Students," *Teachers College Record*, November, 1926.

vocabulary of science subjects offers great difficulty, especially in the junior high school. More attention should be given toward aiding the student in broadening his fund of meanings for science terms and concepts. Science offers an unusual opportunity for developing a precision for meaning because it deals largely with *what is in* a given situation rather than with what should be, or how we feel about it. Science teachers should seize every occasion to demand exact description and expression of meaning which should result from precise and exact observations of phenomena. Loose and inexact expression may be the result of loose observation on the part of the student.

In reading science materials most students fail to make any distinction between reading for pleasure and reading for exact meaning. It is largely the responsibility of the science teacher to teach students how to read science materials.

Students experience difficulty in getting the exact meaning from a science passage because they fail to read analytically and with purpose. It is the function of the teacher to supply the purposes and then to teach the student to read questioningly. What did I wish to get from this passage?—does this agree with my previous ideas on this topic? What is the connection with the problem I am solving? What is the central idea of this passage? If the pupil learns to read analytically many of his difficulties with science will disappear.

One of the most successful devices for securing exact reading from students is the assignment question list. There are several variations of this. A list of thought questions is prepared on the readings, and the students are either asked to write out the answers or be ready to discuss them in class. Questions in this list should be stated in such a way as to require the interpretation and organization of the materials, and their answers should not be direct quotations from the book. One variation of this procedure is to have the students bring to class a list of questions based on the readings. It is also possible to have pupils make lists of important principles, and to write outlines and summaries based on the assignment.

Each of these devices will create a need for close and exact reading on the part of the student.

In collecting information concerning the solution of a problem the student should be taught to collect as large a body of information as possible. He should make use of many sources such as books, diagrams, pictures, and any other visual aids such as motion pictures, stereoscopic materials, etc.

Experiments offer a peculiar opportunity in science for collecting exact information. The science teacher should see to it that every experiment contributes to the solution of a problem. In the past much of our so-called laboratory work has been largely "busy work" and has had little or no value in the solution of real problems.

Full value from experimental work is frequently lost because students have not learned to observe carefully and accurately. They get only general impressions from an experiment and rarely note exceptions or differences. At an early period in the science experience of children much emphasis should be placed on training in careful observation.

The instructor should plan exercises both in and out of the laboratory which will call upon the powers of observation of the student. It is often possible to locate the poor observers by performing a demonstration before the class and then having the pupils respond to questions on a mimeographed sheet.

Once the poor observer is located, special help may be given to him. He may be encouraged to train his powers of observation by such a simple device as looking in a store window containing many articles and seeing how many things he can name after a certain period of observation. Also there are games on the market consisting of rather detailed pictures. After a certain period of observing the picture the contestant is asked to answer certain questions about it. Use of this idea may be made in the laboratory by placing a variety of materials on the demonstration table and then providing a given length of time for observation. The materials are then

covered or removed and the pupils requested to answer prepared questions about the materials.

It is also possible to help the poor observer by making him responsible during a demonstration for observing and recording the evidence obtained. This creates a real need on his part and will serve to give him practice in focusing his attention. It is also interesting to appoint several special observers from among those who are low in the ability and to compare their recordings in a short discussion following the demonstration.

Students should be taught the skills essential to good experimenting, and especially the importance of controlled experimentation. The average high-school student is able to understand and appreciate the need for controlling all factors in an experiment except the experimental variable. Experience has demonstrated that by wise questioning and suggestion the teacher can get students to state the purpose of an experiment, to suggest the experimental factor, and to plan necessary controls to make the results conclusive. Following such a coöperative scheme of planning experiments with the class will take much of the "cook book" out of laboratory work and revitalize it so that it becomes an interesting and valuable method of collecting first-hand information about a problem. An example will make this point clear.

An eighth-grade class in general science had been studying oxidation and had noted that heat was given out in many instances. One girl said that the rusting of iron must be exceptional because no heat was given out when it oxidized or rusted. Her classmates challenged her to prove this and in the resulting discussion someone proposed that an experiment be performed to find out. How could such an experiment be performed? It was finally agreed that if any heat were given out it would be a very small amount and therefore some way would have to be devised to hold it in. The idea of the thermos bottle was proposed. The class had already performed the experiment of iron filings rusting in a test tube over water, so it was suggested that we could let

iron filings rust in a stoppered thermos bottle with a thermometer to show temperature changes. The class was canvassed for thermos bottles and next day excitement ran high as they brought the thermos bottles to class. It was decided to use two experimental bottles and one control bottle. In each of the bottles the students decided to place a measured quantity of water at a given temperature. After rinsing the three bottles with the water the control bottle was stoppered with a one-hole stopper carrying a thermometer. A weighed portion of iron filings was next placed in each of the experimental bottles after which they were closed with stoppers carrying thermometers. Temperature readings were taken by class committees during the day and placed on the blackboard. On the next day the data was examined.

The boys and girls were greatly surprised to note that there had been very little temperature change in the control bottle, but that there had been a sudden rise in each of the experimental bottles followed by a slower rise and then a gradual drop to room temperature.

They were asked to draw inferences on the basis of the evidence and then to further test the inference by repeating the experiment with other materials made of iron such as tacks and small nails. After these tests had been performed, the students were ready to conclude that even in the case of the rusting of iron, heat energy was given out.

It is also essential that students learn how to arrange data for efficient study. The kind of arrangement will depend to a certain extent upon the nature of the data, but usually should be thrown into some sort of tabular form. In any event the student should learn to arrange data neatly and in an orderly manner and should always record exactly what the results are and not what he believes they should be.

In many instances in our present experimental work the student knows the results before the experiment is performed. The laboratory degenerates into a dull and uninteresting place. This can be avoided by letting the students share in the plans for experiments and in making the experiments

function to supply first-hand data in the solution of a real problem. From this point of view much of our present laboratory practice would be open to serious question.

Learning What Evidence Is. Living in a modern world where emotional thinking and appeal are rampant makes it imperative that young people learn what the earmarks of good evidence really are. It is feasible to show them how evidence is regarded by the scientist and will, if properly learned, provide a safeguard against much of the questionable advertising and other practices so prevalent today. The following quotation is taken from an article by Henshaw Ward: [1]

"(1) Science cares only for indisputable evidence. (2) If the evidence is conflicting, science balances the probabilities without running headlong to a conclusion. (3) Unless the evidence so cumulates that almost all competent observers are forced to agree, science suspends judgment. How small a proportion of the population now has any conception of suspending judgment! How salutary it is for any one of us to learn to suspend! (4) Whenever new evidence appears, the true scientist welcomes it; he is as ready to have his previous theory demolished as to have it corroborated. He is guided by a curiosity that cares only for what the new evidence indicates. (5) Science recognizes that no amount of evidence is ever absolutely certain, that no knowledge is everlasting and immutable."

This consideration of "what evidence have you" to support an opinion is closely associated with the judging of relevancy of data, verification of an hypothesis, and other important aspects of problem solving. In his excellent article Mr. Ward states further:

"The teacher who can give his class even an inkling of what true evidence is has made their intellectual lives safer and better."

"If he tries to expound the abstract principle, he will accomplish nothing. He can convey understanding only by

[1] Ward, Henshaw, "The Goals of High School Science," *Harvard Teachers Record*, October, 1933.

putting before the class one concrete illustration after another, and so gradually bringing out the difference between empty 'thinking' and real proof. The humbler the demonstration the better."

The following illustration is taken from the same article by Mr. Ward: [1]

"In all schools the idea is rampant every winter that the climate is changing. 'Oh, yes, we used to have much more snow and much lower temperatures than we now have. I can remember perfectly how different the climate used to be.' But science pays no heed to such perfect memories. It charts the facts that thermometers have recorded each day for half a century. It shows that not the slightest change in climate is discernible. There is no evidence of a change!"

The two examples following were prepared by Mr. Gaylord C. Montgomery of John Burroughs School, St. Louis, Mo.

1. In studying the telephone as one device for modern communication, it was found that the telephone receiver contains a permanent (horseshoe) magnet, on the ends of which are mounted electromagnets. After removing the cap from the end of the receiver, the diaphragm was held above and away from the end of the receiver, and then dropped. It moved to about the proper position, then "stuck" there. An explanation of what they had observed was requested from the class. The reply was: "The magnet attracted and held the diaphragm." "What kind of magnet is contained in the receiver?" "An electromagnet." "What evidence have you?" The receiver which I had carried half way across the room and to which was attached about thirty inches of cord, free at one end, was handed to the pupil. "I can see two cores, each wrapped with a spool of small wire." "What is attached to the other end of the wire?" "Nothing." The concept of conflicting evidence began to develop. "If an electromagnet is attracting and holding the diaphragm, what must flow through the coils?" "Electricity." "Where is the electricity coming from?" "Where is its source?" "There isn't any."

[1] *Ibid.*

2. The foundation of modern electricity was laid by two Italian physicists, Alessandro Volta and Luigi Galvani. At the end of the eighteenth century Galvani discovered the existence of electricity in a flowing state, or the electric current, which passes through media called conductors. His researches led Volta to invent the first electric cell, called after him the Voltaic cell, which is now the foundation of our electric batteries. The ninth-grade pupils had learned, through laboratory experiences, of two sources of electricity; friction, and the transformation of chemical energy into electrical energy by the ammonium chloride cell. They had examined worn-out dry cells, sawed lengthwise, and could recite with reasonable accuracy the principle of the latter: "Electricity can be secured from chemical energy whenever two unlike substances are dipped in solution, provided one of them is acted upon more rapidly by the solution." The day following the development of this concept, the class was asked if any pupil had a dime that he or she would exchange for two nickels. Taking the dime obtained, a piece of wet toweling, soaked in salt-water, was placed between the dime and a penny, and held before the class. The coins thus arranged were handed to the nearest pupil and she was requested to walk down the aisle holding them so that her classmates could make observations at close range. "What name may be applied to this device?" was asked of the class. In a moment hands were waving and the general opinion expressed was to the effect that the girl held a "wet cell." "What is your evidence?" "Wires held to the coins with the other ends of the wires attached to the terminals of a galvanometer would, perhaps, deflect the needle." The galvanometer was supplied and the wires held as described, then reversed with respect to the coins, and the needle thus deflected in each direction. "Have we sufficient evidence of a wet cell?" The suggestion was proposed that a sufficiently large number of such coins, alternately placed, would ring a small demonstration electric bell. This was provided while the pupils emptied their pockets of pennies and dimes and the bell was

rung vigorously. Thus, further evidence substantiated the conclusion.

Interpreting Evidence and Drawing Inferences in the Solution of Problems. In recent years there has been an increasing desire on the part of many teachers to include this aspect of reflective thinking among the desirable outcomes toward which their teaching might be directed. It should be clear at the outset that this aspect of problem-solving behavior is not a specific but is a complex of many skills and abilities. And therefore in approaching the question of how children may be taught to make reasonable interpretations of data it is essential to break the large area down into its simpler abilities and then to consider ways and means of setting classroom situations for developing these. Such an analysis of the general ability to interpret data might involve in part, the following more specific abilities:

(1) The ability to analyze.
(2) The ability to distinguish between fact and assumption.
(3) The ability to discern consistencies and inconsistencies in data.
(4) The ability to recognize fundamental assumptions underlying data.
(5) The ability to generalize and establish principles in the light of data.
(6) The ability to establish causes on the basis of observed effects.
(7) The ability to predict effects on the basis of established causes.
(8) The ability to evaluate data.
 (a) Accuracy.
 (b) Adequacy.

In developing effective skills in students for use in the interpretation of data it is desirable that the learning and evaluation procedures should parallel each other. For the learning process should begin first with evaluation in the form of an inventory to discover which of the specific skills are deficient and should end with evaluation to reveal the extent to which the learning has enhanced the skills. As Raths [1] has

[1] Raths, Louis, "Appraising Certain Aspects of Student Achievement," *Thirty-seventh Yearbook of the National Society for the Study of Education,* Part I, Guidance in Educational Institutions, Chapter III, 1938.

clearly put this point—"Any 'interpreting' situations, whether 'teaching' or 'testing' should give students opportunities to reveal whether or not they possess these skills."

With the above analysis a teacher may study the learning situations which are to be used in the solution of a problem and so plan them that a good selection of the skills and abilities will be practiced by the student during the solution of the problems.

Certain aspects of selecting evidence will of necessity overlap the step of arranging the data. For example it is not possible to arrange data for adequate study unless it has been analyzed at least to some degree. It is possible to begin at an early level in science, certainly by the time a student enters the junior high school, to give considerable practice in analyzing data from almost any problem situation and then to ask the students to list the inferences to be drawn from the evidence. For example in the solution of a problem dealing with the nature of air, the following development is possible:

(1) A drinking glass is pushed down over a cork floating in a basin of water.
(2) Water is allowed to gurgle from a small-necked bottle which has been inverted.
(3) An attempt is made to pour water into a jar which has been stoppered with a one-hole stopper carrying a funnel.

The students are asked to observe carefully what happens in each case and list exactly what they see. After data has been arranged on the blackboard the teacher asks the students to analyze the evidence to see if there are any similarities in the results. Then to note any differences. Following the analysis of the data the students list all of the inferences which may be drawn. These are then checked to see whether the data will support them. If any are found that conflict with the data they are discarded. Those which seem to be reasonable in the light of the data are then subjected to further tests, usually proposed by the pupils. Finally it is possible for them, on the basis of tested evidence, to arrive at the statement that air will occupy space.

This exercise has given practice in careful observation, recording, arranging, and evaluating evidence as well as in the proposing of hypotheses, the testing of hypotheses, and in stating a principle. The next step in the series is to give pupils situations in which the principle is applied in other ways.

In the solution of a problem related to the work of vitamins a student might be confronted with a situation of the following nature:

Health authorities sent to the Philippine Islands following the Spanish-American War found many people ill of beriberi. An investigation revealed that the diet of many of these people consisted of rice from which the outside hulls had been removed. It was further found that when these people were fed with rice which contained the outside hulls, the victims of beriberi improved almost at once.

The students are asked to write down the inferences which may be drawn from such evidence and to propose ways of testing out these inferences.

A problem related to why a person pitches forward in a car that has suddenly stopped or is thrown backward in a car suddenly started, might lead a student to infer a cause or reason for such situations as the following:

(1) A person tends to feel lighter for a moment when an elevator suddenly starts downward, and heavier for a moment when it suddenly starts upward.
(2) A heavy hammer or weight is often placed behind a springy board into which a nail is to be driven.
(3) Rugs are shaken to remove dust and dirt.

Again a student might be asked in a certain situation to predict some of the effects if the force of gravity were suddenly to disappear or to predict whether an acid which has dissolved a piece of magnetized iron will be magnetic.

Evidence that is presented in some graphical form offers excellent material for giving students experience in interpreting data. Among such may be listed, consumer statistics, health graphs, accident graphs, and many others.

Proposing and Testing Hypotheses in the Solution of Problems. The reader is cautioned against the erroneous assumption that, because the several steps in problem-solving behavior are here discussed in a certain sequence, there is any reason to believe this to be the order in which they are used in the solution of a problem. They may be used in this order in the solution of some problems, but in other cases it is quite conceivable that the step of hypothesis might precede the collection of data and follow at once upon the statement of the problem.

In proposing and testing hypotheses for the solution of a given problem, the student may be called upon to use the following:

(1) Ability to judge the pertinency of data for the problem.
(2) Ability toward resourcefulness in setting up hypothesis.
(3) Ability toward resourcefulness in proposing tests for hypothesis.
(4) Ability to compare hypothesis with dependable authorities.
(5) Ability to modify hypothesis in the light of new data. (This with certain of the others listed as abilities are complexes intimately bound up with attitudes.)

It should be said at the outset that this step in problem-solving behavior is probably the one upon which least work has been done in so far as methods of learning are concerned. In conventional classroom and laboratory practice the usual method is to pass immediately from data to conclusion or generalization, without very much time being given to the consideration of possible proposals bearing on the solution of a problem. This of course may be the fault of the type of problems which have been made the basis of the courses, in that the solutions were obvious.

The abilities involved in proposing and testing hypotheses are exceedingly important in modern life and should therefore become a part of the habit equipment of the young people of high-school age. Assuming that these abilities can be taught in such a way as to transfer to other life problems, it is possible that their application might aid students toward a more complete adjustment. Many young people today rush into

decisions and actions without first carefully weighing all factors involved; without suggesting possible results on the basis of evidence, and then acting. It is also possible that many of the frustrations so common among present-day youth may be attributed to maladjustments resulting perhaps from an inability to use the step of hypothesis in problem solving.

To attain many of the outcomes discussed in this chapter, it is not necessary to abandon the content of science courses as now organized and taught and swing completely to the views expressed in such reports as the one recently published by the Science Committee of the Commission on the Secondary School Curriculum of the Progressive Educational Association![1] Much of the present content of high-school science will lend itself, with a slight shift of approach and emphasis, to giving practice in such abilities as those involved in proposing and testing hypotheses. The greatest need is for teachers to develop an alertness to the potentialities in this direction in present materials. An example will illustrate the point.

A class in physics had been working on the principle of the siphon. Demonstrations and readings had been done in the usual manner, and the class had discussed the applications of the principle. Someone raised a question as to the speed of flow of the siphon and the factors which controlled it. The teacher turned the problem to the class and through discussion, several factors which might affect the flow were proposed. Some of the proposed were fluid friction, viscosity of liquid, size of tube, difference of level, density of liquid, etc. In discussing the way in which each of these factors affected the flow, several hypotheses were suggested. The class decided that the best way to discover if and how these factors affected the flow of the siphon would be to carry on some experimentation. Groups were formed with each group taking one of the proposed hypotheses for testing. Each group then devised

[1] *Science in General Education.* The Science Committee of the Commission on the Secondary School Curriculum of the Progressive Education Association, Appleton-Century Co., 1938.

an experiment and designed simple equipment to control all factors except the experimental variable.

The students went to work with more interest and enthusiasm than the instructor had seen in a long teaching experience. The next day brought forth plans of all sorts which were discussed pro and con in the groups and tried out in a preliminary way. The instructor was amazed at the resourcefulness of proposals and the uniqueness of design for some of the experiments.

The experiments were performed under varying conditions, and finally the evidence was presented to the class by each group in turn. In several instances the results reported were seriously questioned on the basis of inadequate controls or careless manipulation. This prompted a period of checking results and other individuals designing equipment and testing out certain doubted evidence. In one or two instances it was necessary to modify the evidence as first reported.

In all, this work on the siphon consumed nearly two and a half weeks. A long time in light of the fact that ordinarily not more than one or two class periods are given to it in the physics course. And yet the returns from that period paid good dividends in added interest in the course and in later tendencies on the part of many of the students to approach their work more scientifically. Throughout the remainder of the year, they frequently requested the use of a similar method in attacking subsequent problems.

In such an approach the ground to be covered has to be sacrificed to the accomplishment of certain other outcomes and this is not always possible or wise, especially where some of the students are preparing for College Entrance Examinations. And yet it would seem from experience that several such exercises spread over the years' work would pay dividends even to the point of making the remaining work more vital.

Drawing Conclusions and Making Generalizations. This step in the problem-solving process follows closely from and is intimately related to the preceding step of testing hypotheses. In

fact it often happens that the tested hypothesis is the conclusion to be reached. Some of the following abilities may be useful in the effective carrying out of this step:

(1) Competency of expression.
(2) Judging the consistency of the generalizations in the light of the hypothesis and other established evidence.
(3) Establishing principles and generalizations in the light of the hypothesis and other tested evidence.
(4) The ability to classify conclusions under a generalization.

The illustrations cited above seem to show how classroom situations in science can be so handled as to give practice in drawing conclusions from tested evidence. Many of the experiments now performed as a part of the courses in general science, biology, chemistry, and physics offer untold opportunities for giving practice in drawing valid and logical conclusions from evidence. Science teaching should use the data of experiments more as a basis of class discussion. Also demonstrations should be used more to furnish evidence from which conclusions may be drawn.

It is quite true that the solutions of all problems do not lead to new generalizations. Often a conclusion merely supports another generalization. In the use of this ability, however, it is essential that students be trained in classifying conclusions where they do support established generalizations and in the forming of new generalizations when they do not support those already formulated.

The assumption should not be made that the development of problem-solving abilities works against the building up of those basic concepts and generalizations which form the warp and woof of specialized science and their social implications. Quite to the contrary. In the solution of problems which are worth-while to him, the learner will build an ever enlarging background of meanings for these generalizations as he meets and solves his problems on higher and higher levels.

Applying Principles in New Situations. As it is important that the cycle of reflective thinking should start with problems that are inherently interesting and worth-while to the learner, so is

it essential that the cycle close with the application of principles to new situations which are close to his life experience. This should enable him to bridge the gap between the artificial classroom situation and the real life situation. It should also enhance the probability of transfer for the several abilities of problem solving which have been sought as desirable outcomes.

In attempting to provide classroom experiences which may lead to more effective application of principles, the following specific abilities may be used:

(1) Ability to recognize the common and identical elements in the principle and a new life situation.
(2) Ability to analyze or interpret new situations in the light of conclusions reached.
(3) Ability to synthesize elements in a new situation toward the formulation of new and unique problems.

It is equally as difficult to separate the learning or development of the ability to apply principles from its evaluation as was the case in the ability to interpret data. Each testing situation becomes a learning situation in so far as it reveals the weaknesses of the student with respect to that ability.

A teacher who has set this ability up as a desirable outcome no doubt would describe its attainment in terms of student behavior. For example a teacher of biology might reasonably expect his students to apply the principles of biology in predicting or explaining natural phenomena or situations which had not been discussed in the classroom. Thus the attainment of the objective might be revealed by confronting the student with unique situations and asking that predictions be made and reasons given to substantiate the predictions.

The process of building up a set of principles in any given area of science through problem-solving techniques is an inductive process, while the application of the principle to new situations is largely deductive in nature. Principles are generalizations built up inductively from accumulated evidence, always enlarging and taking on new meanings in the light of new evidence. Principles may be used in predicting what will happen under a given set of circumstances or in the explana-

tion of some phenomenon or event which has taken place. In either case, the method applied is deductive rather than inductive.

From the standpoint of learning, principles are very valuable. Since they are the result of cumulative and generalized experience, they make up the bases for classification of conclusions reached through problem solving. They are also economical in learning since it is much easier to remember a given fact or truth as it is related to some broad generalization than to remember it as an isolated element.

The Evaluation Staff of the Commission on the Relation of School and College of the Progressive Education Association [1] have developed some very valuable techniques and materials for evaluating the ability to apply principles which will be referred to and discussed at some length in Chapter VII bearing on Evaluation. However, in developing these materials particularly for evaluation they have made some very significant contributions to the learning of the ability to apply principles. This is of course quite obvious when one considers the use of such tests as they have developed, in relation to their diagnostic value. When a pupil has a weakness in any aspect of problem solving revealed to him through a test, there develops at once one of the most significant learning situations possible. For the student is anxious to correct his error, and the teacher is in a position to prescribe remedial instruction that meets the needs of the student.

Aside from this very important contribution to learning, however, the Evaluation Staff has made studies of the responses of young people to test items based on applying principles. These findings have been summarized in one of their bulletins dealing with the Application of Principles.[2]

They have found that when the ability to apply principles is imperfectly learned, it may be due to one or more of the following causes:

[1] *Ibid.*

[2] Progressive Education Association, *Evaluation in the Eight-Year Study*, Bulletin No. 5 (P. E. A. 898), December, 1936. "Application of Principles."

"(1) Lack of knowledge of principle involved.
"(2) Failure to see that the principle applies in a given situation.
"(3) Inability to tell why a given thing happened, even though the pupils can explain what happened or predict what will happen."

Further analysis of the written papers of these students revealed to the Evaluation Staff that in applying principles they may give false reasons; give irrelevant reasons for predictions; make unwarranted assumptions; use poor analogies; give poor authority; or make use of misconceptions of truth. From the standpoint of method, these findings are exceedingly important for they point the way to the specifics in learning that teachers must be cognizant of, if the pitfalls in applying principles are to be avoided.

The lack of knowledge of a principle involved means probably a low degree of mastery of the facts which have gone into the establishment of the principle. The failure to see that a certain principle applies in a given situation would seem to indicate that the student had made too few associations of the principle with real life situations.

There has been a point of view current in science teaching that if the laws and facts of a given science were thoroughly mastered, other abilities such as those involved in problem-solving behavior would develop. This is a false and unwarranted assumption and must be guarded against. If it is desirable that students acquire such abilities as outcomes of a science course, they must be taught for directly. This does not mean that there will be any less emphasis on content, but that content mastery will cease to be an end in itself and become the vehicle through which significant problems are solved and other desirable outcomes attained. There is some evidence to show that content mastered in the solution of worth-while problems has greater permanence than content mastered for its own sake.[1]

If science teaching is to serve its greatest possible function it must train young people to think. Thinking must be done

[1] *Ibid.*

with laws, facts, and principles, and so there is no quarrel with content, as such, on the part of those interested in problem-solving values, but only with the use to which content is put.

Developing Appreciations in Science. We are living in an age so intimately associated with technological developments that, as was pointed out in Chapter II, it is essential for young people to acquire a background of appreciations from the several areas of learning so that they may adjust to the problems of life with greater understanding and satisfaction. It is the obligation of science to supply those appreciations which are peculiar to its field.

The development of appreciations in young people will naturally vary in method with the level of instruction. In the early years of the junior high school, students are interested in stories of adventure and romance, while later on their interests shift as they read the historical materials to see how some of the great scientists worked; what their problems were and how they solved them. In English classes they are reading *Moby Dick* and *Treasure Island.* They are thrilled by the romantic adventures so vividly told by Jules Vernes. This interest, properly directed, may become a powerful motivating factor for science study at these levels.[1] There is so much worth-while material in the field of discovery and invention upon which to draw, that hardly a problem will be raised which will not have some interesting historical antecedent.

The story of Davy and the discovery of the safety lamp, of Robert Koch and the discovery of the cause of anthrax, may be used to show the young people how the scientist solves his problems. The fields of astronomy, physics, chemistry, biology, and geology are all filled with interesting and worth-while materials of this type which should become a part of the background of every boy and girl who studies science. If the student is directed to such books as the *Life of Pasteur* by Vallery-Radot, or the *Microbe Hunters*, or *The Hunger Fighters*

[1] A splendid source of such material for science is the book *Heroes of Science*, by Colton and Jaffe, published by Little, Brown and Co., 1934.

by Paul DeKruif, it is possible for him to study the careful and systematic approach used by scientists in solving their problems.

In connection with this aspect of learning science, the teacher may prepare a series of analysis sheets based on certain readings which will bring out for the student the important points as related to problem-solving techniques.

In the science courses which come late in the high school it will be found that historical and biographical materials may be used for giving perspective and setting to modern problems of science which have certain social implications. For example in the study of many problems of transportation or communication, a knowledge of the historical and biographical backgrounds will give meaning and enrichment to the solution.

Appreciations as with problem-solving techniques must be taught for directly and sought by the learner if they are to be realized as outcomes.

Developing Attitudes through the Study of Science. Problem solving in all of its steps is closely associated with a group of attitudes or mind-sets which are very important as outcomes of learning. Up until quite recently it has been assumed that if the content of science courses was thoroughly learned, scientific attitudes would develop concomitantly. This seems to be doubtful. Recent thinking in the field seems to indicate that they must be sought directly through procedures in the classroom if they are to be realized. Although relatively little is known or has been done on classroom techniques for developing attitudes, this section will be devoted to a consideration of certain techniques which seem to give some promise in this direction.

Several lists of scientific attitudes have appeared in the literature of this field. The following list [1] is very similar to these, but is perhaps unique in that the attitudes are classified under the various steps of problem solving.

[1] Prepared by a Committee of Teachers at John Burroughs School, Clayton, Mo.

I. Interest in the problem.
  (a) An active and intelligent curiosity.
  (b) Sensitivity to problem situations.
  (c) The disposition to note dissimilarities as well as similar ties.
II. Collecting evidence on the problem.
  (a) Freedom from superstition and unfounded beliefs.
III. Setting tentative hypotheses on a problem.
  (a) Basing judgment only on facts, recognizing that the rel tive truth changes as knowledge is extended.
  (b) Intelligent skepticism of data and authority.
IV. Testing tentative hypotheses.
  (a) Willingness to modify his hypotheses upon the bases newly discovered, reliable evidence.
    (1) Open-mindedness.
    (2) Tolerance.
    (3) Intellectual caution.
  (b) Developing perseverance in seeing a problem throug to its logical conclusion and displaying a willingness t act even though the data may be tentative.
V. Drawing conclusions and generalizing.
  (a) Developing confidence in one's own ability to approac a problem effectively.
VI. Application of principles to new situations.
  (a) Eagerness to discover and learn methods of work mor efficient than one's own.

In attempting to develop the various abilities involved i problem solving and their attendant attitudes, the teache should be alert to build up in the student safeguards agains the development of faulty attitudes. Perhaps this is the mos direct and effective method of developing positive attitude in the student. Below are listed safeguards for the severa attitudes listed above.

I. Safeguarding interest in problems against:
  (a) Undirected and irrelevant approach.
  (b) A narrow field of observation.
  (c) Inattention to detail.
  (d) A tendency to disregard exceptions.
II. Fortifying himself against superstitions and unfounde beliefs by:
  (a) Establishing causes of superstitions.

(b) Rejecting unfounded beliefs on the basis of reliable evidence.
(c) Recognizing and controlling ethical, social, personal, and religious prejudices.
(d) Controlling emotional bias to accept superstitions or unfounded beliefs.

III. Guarding against an hypothesis based on facts accepted at the present time, but whose relative truth may change with the extensions in knowledge.

IV. Safeguarding against dogmatic decisions by a willingness:
(a) To recognize that an hypothesis may be only tentative.
(b) To suspend judgment on conclusions which affect future action.

V. Safeguarding against the uncritical acceptance of data as authority by:
(a) Maintaining a questioning attitude.
(b) Examining the relation of data or authority to available facts.

VI. Safeguarding against discouragement because of apparent difficulties.

VII. Safeguarding against the use of inefficient and ineffective methods of work.

VIII. Safeguarding against unconcentrated effort and vacillation.

Curtis [1] in an investigation of the values of extensive reading in science found that this did tend to give some training in scientific attitudes, but that the gains were small when they were compared with those made when definite instruction in scientific attitudes was given. Curtis has also worked out with general science classes considerable material and accompanying techniques for direct instruction in scientific attitudes.

Caldwell and Lundeen [2] have made a thorough experimental investigation of superstitions and other unfounded beliefs as they are related to certain units in general science. They have prepared teaching materials to accompany regular in-

[1] Curtis, F. D., *Some Values Derived from Extensive Reading of General Science*, Bureau of Publications, Teachers College, Columbia University, New York, 1924.

[2] Caldwell, Otis W., and Lundeen, Gerhard E., *An Experimental Study of Superstitions and Other Unfounded Beliefs*, Bureau of Publications, Teachers College, Columbia University, New York, 1932.

struction in general science which is designed to safeguard against these superstitions and unfounded beliefs.

Davis [1] and others working as a committee of the Wisconsin Education Association have made an investigation attempting to discover the characteristic attitudes of the scientist. On the basis of this study tests have been constructed and given to several thousand students in various courses in science.

In general there has been much more work done in the field of attempting to measure the presence or absence of scientific attitudes than has been done in a direct attempt to devise methods to inculcate these attitudes. This probably is the correct approach, for it is important to know to what extent present methods of science instruction develop these attitudes before changes can be made with the assurance that practice will be improved.

However, there are some things which can be done without test results to better insure the development of desirable attitudes in the young people who study science. Continued contact with good scientific attitudes through reading of the lives of great scientists, association with a teacher who practices them, etc., will aid in fostering and developing them.

Perhaps the greatest force at present in the development of desirable attitudes is a teacher who practices them day after day in his classroom. The atmosphere of such a classroom will be charged with a spirit of friendly criticism of procedures, data, hypotheses, and conclusions. It will encourage an intelligent questioning of authority and maintain a skepticism for reported evidence. Emotional and wishful thinking will be questioned, and prejudice and intolerance will find no place. Facts and assumptions will be clearly distinguished, and hypotheses modified in the light of new evidence. If such an atmosphere could be maintained in our science classrooms we could go a long way toward inculcating desirable attitudes even without the benefit of test results.

[1] Science Committee, Ira C. Davis, Chairman, Wisconsin Education Association, Wisconsin High School, Madison, Wisconsin.

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Chapter V

The Use of Individual Laboratory Work and the Demonstration Method in Teaching Science

INDIVIDUAL LABORATORY WORK VERSUS DEMONSTRATION LESSONS

A CONSIDERABLE number of experiments have been reported of attempts to determine the relative merits of individual laboratory work and demonstration methods of teaching science. It is not feasible to give a detailed report of all these investigations here. However, it does seem desirable that science teachers at large become familiar with the conclusions arrived at by many of the investigators.

Stuit and Englehart [1] have made an excellent critical analysis of the lecture-demonstration *versus* the individual laboratory method of teaching high-school chemistry. The following is their summary of conclusions:

"In comparing the experimental evaluations of the methods of teaching high school chemistry, one is impressed by the variability of conclusions reported by the various investigators and the general inadequacy of the experimental techniques. It is evident that all the valuable outcomes of any one method are not tested by all the investigators. Much of the data seems unreliable and invalid due to lack of validity, and reliability of tests, doubtful control of teaching conditions, and the use of small, unrepresentative groups. Few writers base their conclusions on more than one trial. This hardly seems justifiable, for in any science, results require re-examination before they can be assumed to be dependable. In hardly any case is the method used by any one instructor exactly like that used by another. There is no standard demonstration or laboratory method. However, in order to arrive at a few general con-

[1] Stuit, Dewy B., and Englehart, Max A., "Critical Summary of the Research on the Lecture-Demonstration versus the Individual Laboratory Method of Teaching High School Chemistry," *Science Education*, 16:380–91, 1932.

clusions, it seems advisable to draw up a summary of the conclusions made by the various investigators; of these, the following are some of the more outstanding:

I. *CONCLUSIONS CONTENDING THAT THE LABORATORY METHOD IS SUPERIOR.*

(1) "There is a slight indication that material was better retained when taught by the individual laboratory methods." (Anibal)
(2) "The order of preference of the methods studied places the individual laboratory method before the demonstration method." (Horton)
(3) "In every respect the lecture method is least effective in imparting knowledge to high-school students." (Wiley)
(4) "For permanent learning the laboratory method is perhaps slightly superior." (Wiley)
(5) "For providing knowledge and method of attack, the laboratory method is superior for the inferior pupil." (Knox)

II. *CONCLUSIONS CLAIMING THAT THE DEMONSTRATION METHOD IS SUPERIOR.*

(1) "Bright pupils are more likely to profit by the lecture-demonstration method than are the others." (Anibal)
(2) "Dull pupils profit more from demonstration than from individual laboratory work." (Carpenter)
(3) "The lecture demonstration takes less time and costs less." (Anibal)
(4) "The teacher (demonstration) method is best." (Nash & Phillips)
(5) "Lecture-demonstration method gives better control over the individual since all are under teacher guidance." (Pugh)
(6) "For purpose of providing knowledge for both immediate and permanent retention and for the purposes of providing technique or handling new problems, the demonstration method is much to be preferred to the laboratory method in the case of average superior pupils." (Knox)

III. *CONCLUSIONS CONTENDING THAT THE STUDENTS ACHIEVED EQUALLY WELL BY EITHER METHOD.*

(1) "Immediate retention is about equal in both demonstration and individual-laboratory methods." (Anibal)
(2) "There is not as great a difference as is ordinarily supposed in the value of the three methods: lecture, textbook, and laboratory, so far as imparting knowledge is concerned." (Wiley)

(3) "The results of this experiment point to the conclusion that the majority of the students in high-school laboratory-chemistry classes, taught by the demonstration methods, succeed as well as when they perform the experiment individually, if success is measured by instruments which measure the same abilities as are measured by these tests, namely specific information and ability to think in terms of chemistry." (Carpenter)

IV. *GENERAL CONCLUSIONS BASED ON EVALUATION OF THE REPORTED RESEARCH.*

After considering the above conclusions the writers have arrived at a few ideas which seem justifiable in the light of evidence given by this study.

(1) No method can be considered to be the best in every case. The objectives of chemistry teaching, the preference of the teacher, the nature of the pupils, and the facilities of the school will largely determine which method should be used.
(2) In small schools where money and space are not plentiful, the lecture-demonstration method seems to be the most practicable.
(3) The written test cannot be used to test all the outcomes of a course in high-school chemistry. Some sort of manipulative tests seems necessary to test the laboratory skills.
(4) The problem of the relative merits of the lecture-demonstration and individual-laboratory methods still seems involved and as complex as ever. More careful experimentation, involving careful control of nonexperimental factors and reliable testing, is needed in order to justify any definite and final conclusions. When experimentation has shown the relative superiorities of the methods in terms of outcomes the methods should be evaluated in terms of the value attached to these outcomes.

The conclusions arrived at by the investigators vary greatly and are indecisive. As a result a controversy has arisen among science educators. Some hold that these investigations warrant the complete abandonment of the individual laboratory work in secondary-school science with the substitution of the demonstration method in its stead. Others claim that little or nothing has been proved by these investigations. It is

likely, however, that science teachers will continue to find both laboratory work and demonstrations necessary for good science teaching.

The demonstration method does save time and expense. A saving of time from fifteen to fifty per cent has been reported by investigators. Anibal reports that the cost for a class of thirty taught by the demonstration method is only seven per cent as much as for a class where pupils work in twos at a table.

From the standpoint of economy it would seem that *individual laboratory work should be assigned to a pupil when it is necessary for him to experiment to obtain information essential to the solution of his problem and which cannot be obtained first hand by other means or when it is desired that he acquire certain manipulative skills.*

In any event when individual laboratory work is assigned, it should be conceived as a means to an end and not an end in itself. Much of the laboratory work done in our present set-up is open to serious criticism, because in many cases it is little more than a pupil going through a set of motions following directions of a "cook-book recipe" type. It also frequently happens that pupils are asked to do laboratory work at certain hours, regardless of whether or not a need for it has arisen.

CONTROLLED EXPERIMENTATION

One of the claims advanced for science is that it has within it the potentialities for teaching logical reasoning and for cultivating proper habits of thought. The science laboratory would seem to be a natural place for pupils to engage in problem-solving activities. Unfortunately, too frequently the workbooks are of such a nature that the pupil has little or no opportunity to engage in reflective thinking. Nor is the pupil given much instruction in methods employed to safeguard thinking.

Intellectual processes and skill may be acquired through practice. Basically the scientific method is a problem-solving method, and therefore if it is a worthy outcome of science instruction, pupils should acquire facility with it along with

a mastery of the laws, principles, and facts of science. Pupils need to be given practice in discovering problems, setting hypotheses, and in devising control experiments as a basis for verifying or rejecting proposed hypotheses.

a. HYPOTHESES. An hypothesis is a tentative supposition through which we endeavor to solve a problem. It is a cautious attempt to discover order in any group of facts. Pupils should learn that the methods of science depend on fruitful hypotheses and that no hypothesis deserves serious attention unless it can be put to the test of observation, either directly or indirectly.

b. CONTROLLED EXPERIMENTS. The experiment is the heart of the scientific method. There is an urgent need for science teachers to carry on laboratory work in such a way that pupils will learn the meaning and use of "controls" in experimentation.

Science teachers should encourage their pupils to study and analyze the work of famous scientists; how Robert Koch [1] solved the problem of the cause of the disease anthrax, how Galileo discovered the laws of falling bodies, how Gregor Mendel discovered the first laws of heredity, or how Pasteur discovered preventive vaccination for anthrax. These are thrilling stories through a study of which the pupil may gain a clearer meaning of controlled experimentation and a better understanding of the attitudes and thinking which characterize the work of a scientist.

In order that we may further clarify the importance of the use of "controls" in experimentation let us examine several typical illustrations.

1. Do plants give off carbon dioxide? This is a problem which may arise in a science class. A typical procedure in this experiment is as follows: A little water is placed in the bottom of a wide-mouthed bottle. Some green leaves with their stems are cut from a healthy plant. The leaves are put in the jar with their stems in the water. Some limewater in a small dish is placed in the jar and the mouth of

[1] See Heiss, Obourn, and Manzer, *Our World of Living Things*, Webster Publishing Co., p. 2, 1936.

the jar is covered. After a while the limewater becomes white and milky. The pupil may report that this shows that leaves of plants give off carbon dioxide. But can he be sure this is true? Where is the control? It may be that the limewater turned milky from the presence of carbon dioxide in the air. The pupil must be made to see the necessity of setting up a control to insure reliability of conclusions drawn. He could set up another jar with all conditions the same except that he would not put any leaves in it. Or he might apply a thin coating of vaseline to the upper and lower surfaces of the leaves and repeat the experiment.

2. Another common experiment is the one on plant transpiration which raises the problem "Do leaves of plants give off water?" The pupil is instructed to support a leaf of a plant by a piece of stiff cardboard with the stem extending into a glass of water. He then covers the leaf with another glass and places it in the sunlight. As mist gathers on the inside of the upper glass the pupil reports that this shows that leaves of plants give off water. Should the teacher leave this conclusion unchallenged? A number of questions arise. It may be that if this apparatus were set up without the leaf, under exactly the same conditions, the mist would form anyway.

Even if his conclusion were true for this leaf was it a typical leaf? Would leaves from other plants give the same results? Perhaps the teacher should require the pupil to repeat the experiment using leaves from a large number of species of plants. When Pasteur tested the efficacy of preventive vaccination against anthrax he first vaccinated twenty-five sheep and when they had recovered he vaccinated them again and used as a control group twenty-five sheep which had not been vaccinated before. The twenty-five sheep which had preparatory vaccination lived whereas the other twenty-five all died. His results were all the more convincing because he made his test between two groups of individuals rather than between two individuals.

The pupils should understand clearly the necessity of permitting *only one variable in an experiment*. The science of genetics was begun by Gregor Mendel, not because Mendel was such an intellectual giant that he could analyze the complex results which had baffled his contemporaries in breeding experiments, but because he had the brilliant idea of simplifying

his experiments to the point where he was dealing with only one variable at a time.

ROOMS AND EQUIPMENT NECESSARY FOR SCIENCE CLASSES

Science courses include three general types of activities; recitations, demonstrations by pupils and instructor, and individual laboratory work. Three general plans are in use to meet these needs: (1) A demonstration-recitation room with a separate laboratory; (2) Laboratories with a demonstration table and student table arm chairs; (3) A single room with special type laboratory tables which permit both standing and sitting which may be used comfortably by pupils when watching a demonstration or engaged in a recitation.

Plan (1) of having a science classroom separated from the laboratory offers decided disadvantages. Separate rooms do not allow much flexibility in work. Even where it is possible to change from classroom to laboratory at will there is a loss of time, confusion, and an economic loss of having a room empty. Parker, in a comprehensive study of eight cosmopolitan high schools in New York City, found chemistry laboratories with a total capacity of 4,350 students but with a total enrollment of 1,787 students or 41% of the capacity. Parker also found the physics laboratories used but 56% of their capacity. In smaller schools the waste may be even greater.

In view of the great economic loss due to having separate science classrooms and laboratories it seems advisable to have science rooms equipped for general classroom activities, demonstration work, and laboratory work. Such a room also permits of a quicker change from one type of activity to another and provides for better coördination between classroom and laboratory work. The teacher may stop individual laboratory work at any time and assemble his class for instruction or demonstration.

A well-equipped combination laboratory-classroom will contain the following:

(1) Student chairs.
(2) A demonstration table equipped with running water, sink, gas, electrical outlets, drawers, and cupboards.
(3) Laboratory tables.
(4) Bulletin board.
(5) Wall blackboard.
(6) Chart case.
(7) Cabinet for objects, specimens, and models.
(8) Lantern outlet and projection screen.
(9) Provision for darkening the room.
(10) Adjoining stock room and dark room.
(11) Aquaria, terraria, and receptacles for growing plants when the room is to be used for teaching general science and biology.
(12) A workbench and set of wood and metal tools.

LECTURE TABLE DEMONSTRATIONS

Teaching by the demonstration method is an integral part of science instruction. Science can never be adequately learned entirely from books. Beginners in science should be shown the materials and processes that are being talked about, and eventually they should handle the things themselves.

The science teacher who wishes to become a good demonstrator should know how to handle materials. He should also acquire skill in cork boring, soldering, cementing, drilling, glass working, and other minor operations of the worker with laboratory materials.

RULES FOR DEMONSTRATING.

There are certain fundamental rules to follow in demonstrating. First and foremost the *experiments should work.* Every time the teacher has to say "well, this is what should have happened" the confidence of the pupils is lessened. If, as it sometimes happens with the best demonstrators, some unforeseen difficulty arises during a demonstration it is best to diagnose the trouble, explain the situation to the class, and tell them that you will try to correct the difficulty. Then, either perform the demonstration at another class period or ask the class to present possible reasons for the failure of the experiment.

Experiments Should Be as Nearly Infallible as Possible. The secret of success in demonstration work lies in adequate preparation for the work before class time. No matter how experienced a teacher may be, he should set up the experiments and rehearse them before his class appears.

The Materials to Be Used in a Demonstration Should Be Carefully Arranged on the Demonstration Desk before the Class Enters the Classroom. It is too late to set up apparatus after class has begun. It is very disconcerting to the pupils to watch the teacher fumbling around in drawers or closets for a piece of equipment which should have been on the table before the lesson began. In most cases where demonstrations call for definite quantities of chemicals it pays to have the stipulated amounts weighed out or measured out before class time.

The Apparatus Should Be on a Large Scale. The size of the apparatus which is best depends in part upon the size of the class. Obviously the apparatus must be large enough to permit every student in the room to see it clearly. Experiments which do not permit performance on a scale large enough for every pupil in the room to see clearly should hardly be attempted as demonstration experiments.

Demonstration Experiments Should Be Simple and Speedy. It is advisable in demonstration work to use simple set-ups. Long-drawn-out experiments with complicated and cumbersome apparatus are out of place for demonstrations. Pupils want to see things happen, and interest in the experiment lags when they have to wait too long. Other things being equal the teacher should see to it that demonstrations move on quickly to a conclusion.

An Element of the Unexpected Sometimes Increases Interest in a Demonstration. It is doubtful, however, whether a demonstration should be shown simply because it is spectacular. Every demonstration should raise a problem, illustrate or help to make clear some important fact or principle, or illustrate an application of science. There are quite a few spectacular experiments which should be utilized by science teachers, but

their scientific importance is to be emphasized rather than their value as entertainment.

Apparatus Used in a Given Demonstration Should Be Stored Away Intact until It Is to Be Used Again. This practice through succeeding years results in much economy of time for the busy science teacher. If this plan causes too much "dead stock" a modification of this plan may be used in which such articles as jars, flasks, beakers, and ironware are kept in common use, but only special pieces such as bent tubing and special pieces of apparatus are retained in some special place for future use.

COMMON ERRORS IN DEMONSTRATION.

The following list of statements gives typical errors in demonstrations made by beginning teachers. The list was compiled by Selberg[1] from observations of thirty-six student teachers in general science over a period of three years.

(1) The apparatus was not ready for use.
(2) The teacher failed to show how the demonstration fitted into the problem of the unit.
(3) The teacher failed to direct the student's attention to the important facts of the experiment.
(4) The teacher failed to allow pupils time to record data.
(5) The teacher failed to use the blackboard to aid the pupils in visualizing or comprehending a process, a plan, or the setup of the experiment whenever the demonstration demanded it.
(6) The teacher failed to make clear to the student the reason for employing a certain technique and a control for the experiment.
(7) The teacher used more of the simple recall type of question.
(8) The teacher used a vocabulary unknown to the majority of the students.
(9) The persistent and continuous talking by the teacher did not challenge or stimulate the pupils to talk or ask questions.
(10) The minor facts were given as much consideration as the major ones.
(11) The teacher failed to aid the pupils in applying a generaliza-

[1] Selberg, Edith M., "A Plan for Developing a Better Technique in Giving Science Demonstrations," *Science Education*, 16:417–20, 1932.

tion when the the pupils themselves were incapable of completing this final step in learning.

(12) The teacher formulated the results and generalization rather than requiring the pupils to do so.

(13) The student's interest for further study was overlooked or not stimulated.

(14) The teacher failed to emphasize the generalizations.

(15) The teacher failed to encourage the pupils to suspend their judgment until adequate data upon the problem were obtained.

(16) Insufficient drill was given in the information of the generalization or its application.

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Chapter VI

The Importance of Reading in Learning Science

COLLECTING evidence or material on a problem is one of the essential steps in problem solving. Very seldom do young people have a sufficient background of experience to enable them to proceed at once from the statement of a problem to an hypothesis for solution. It is necessary for them to collect evidence. At other places in this book the techniques of observation, conference, controlled experimentation, and other ways of collecting evidence have been discussed. In this chapter we will take up the problems and techniques of collecting evidence through reading.

Reading is the method most widely used by young people in collecting evidence. Observations and deductions made by others have been recorded, and in many cases these materials become available for use in solving a problem only through the medium of books, newspapers, magazines, or pamphlets. As teachers, we often assume reading ability on the part of the pupils without taking any steps to really know the extent to which they read effectively. There is little doubt that a considerable portion of the difficulties of pupils with science materials originate in their inability to use the materials and comprehend the meanings.

Young people receive most of their reading instruction and probably most of their reading experiences through English and language classes. In these experiences the pupils are called upon to do a certain type of reading and thus develop specific reading habits which may or may not be useful in reading in other areas. It is also true that these reading habits are further set by the kind of leisure reading done by the young people. Most of their leisure reading is done for pleasure and not for retention or for exact meanings. Thus it is not surprising that when these students with a definite pattern of reading habits come to other areas where a different type

of reading is demanded, they experience some difficulty. It is also true that teachers in the areas other than English have assumed that responsibility for the development of good reading habits was strictly a problem for the English department. It is essential that this point of view be broken down and that in any area, such as science, where a special type of reading is demanded, the science teacher assume responsibility for discovering the difficulties and improving the reading techniques of the pupils. This involves first knowing the important skills and abilities involved in the specialized reading; second, discovering the weaknesses of pupils in these abilities; and third, planning procedures for developing the skills and abilities.

Difficulties in Reading Science Materials. Reading specialists have built up in the minds of both pupil and teacher the belief that there is some great virtue in the ability to read with great speed. This is no doubt true in certain types of reading, but the fact is that it is not true in science. In science materials passages are often packed with words which are in themselves concepts made of many interrelated partial meanings. In reading such passages it is essential that a student weigh each word and perhaps engage in interpretation, inference, or application. Certainly in such a situation speed is not a virtue.

It is of little value to a pupil if he reads rapidly and in so doing reads falsely. Where he is forced to read for exact meanings or precise comprehension of the thought the penalty for not doing so may be severe. A reader who fails to grasp the exact meaning of questions asked in tests, the directions which are printed for an experiment, or the exercises set up in a workbook, may not only come out without the information needed, he may actually be led astray. All further activities, initiated by and dependent upon reading, are nullified.

In the area of science there is a body of evidence which clearly reveals the almost impossible task that the technical vocabulary of the various subjects imposes on the student. If he were to do no more than master this vocabulary in the

span of nine or ten months, he would make a fine achievement of a sort. When we realize that in many of our science textbooks there exists a technical vocabulary of several hundred words not found in the ten thousand most commonly used words in the English language, we are able to see in part a reason why young people have difficulty in comprehending reading materials in our field.

The solution of this problem is in part the responsibility of the writers of textbooks and in part a problem for the science teacher. Recently Curtis [1] has made available a comprehensive study of the vocabulary problem in science. This scholarly study should prove most valuable to textbook writers in the field of science, for it shows clearly those words in the various specialized sciences which need precise definition for young people.

As writers of textbooks become more aware of the seriousness of the problem of vocabulary in the learning of science, there will no doubt come some simplification of the technical terms used. It is also equally true that in a specialized area where many words have come to represent concepts, it will not be possible for writers to oversimplify the vocabulary. It is here that the teacher must assume responsibility for helping the student through other learning experiences to build up meaning and understanding for the difficult technical words.

Placing a glossary in a textbook is a partial solution for the problem of vocabulary. However, it is generally true that pupils do not make use of a glossary any more than they make use of other aids placed in a textbook. Teachers should develop the glossary and dictionary habits in students and insist on precise and accurate definition of words. It is also important that textbook writers realize that words must be defined in the body of the text if they are to become a permanent addition to a student's vocabulary.

Inefficiency and ineffectiveness in reading often result from the failure of the student to know about and to use the various

[1] Curtis, F. D., *Investigations of Vocabulary in Textbooks of Science for Secondary Schools*, Ginn and Co., Boston, 1938.

aids in a text or reference book. It is quite common to see a student looking for a page reference to a key word, using the table of contents instead of the index. A teacher should be very certain to acquaint the student with the various parts of a text or reference, and the proper use of each. He should point out devices, such as bold-faced type, italics, underlining, etc., used by the author for special purposes. It is also essential that pupils be given practice in the use of these devices, either during supervised study or through written exercises. Time thus spent will be repaid in more effective reading later in the course.

DEVELOPING GOOD READING HABITS. As has already been stated the science teacher should assume responsibility for the development of effective reading habits in his special area. There is little doubt that many of the failures in science result from the inability to read related materials. Also, if we are going to realize any of the outcomes set up for science either in the form of knowledges, appreciations, attitudes, or skills in thinking, the students must develop good habits of reading.

In the preparation of this section many excellent suggestions have been obtained from *A Handbook on Reading for all Teachers of Secondary Schools*,[1] and *An Experience Curriculum in English*,[2] two excellent publications which should be in the hands of every teacher of science.

In so far as effective reading of science materials is concerned, the main problem is not one of reading for enjoyment, but rather one of reading for intellectual comprehension. This is not to imply that science is void of the other types of reading materials, but rather to emphasize that for purposes of solving problems, most of the reading materials are used for the collecting of evidence. Reading for intellectual comprehension in science is probably not greatly different from reading in the other specialized areas except for that vocabulary and phraseology which is peculiar to science.

[1] The New Jersey Secondary School Teachers Association, 1936.
[2] National Council of Teachers of English.

Some of the problems involved in reading have been analyzed as follows:

(1) The recognition of symbols, and the association of meanings with each.
(2) The synthesis of small thought units into larger meaning units.
(3) The selection of pertinent elements and the rejection of others.
(4) The organization of thoughts according to the purposes with which the reading was done.

If the science teacher is alert to such difficulties offered to young people by reading, he should be in a better position to build up effective reading habits. This, of course, assumes that the teacher will make frequent opportunities for the pupil to reveal his reading ability. It is also important that the pupil be made more aware of problems involved in reading science materials and that he be encouraged to diagnose his own difficulties and attempt to correct them.

The following list of skills involved in effective reading have been included so that the teacher may be rather specific in discerning the difficulty of a pupil and in proposing remedial work:

(1) The ability to read with a definite purpose or problem in mind.
(2) The ability to determine the author's point of view and central theme.
(3) The ability to summarize.
(4) The ability to associate what has been read with the reader's experience.
(5) The ability to evaluate a passage for the purpose for which it is being read.
(6) The ability to vary the rate of reading both with the purpose and the difficulty of the materials.
(7) The ability to read in the midst of distraction.

For nearly every one of these skills it is possible for the teacher to set practice conditions in the classroom. Such periods of practice need not be lengthy but should be frequent especially at the beginning of a course while the teacher is attempting to locate the reading problem cases in a class. In the junior high school it has been found that a little time in

the supervised study period devoted to individual reading aloud will reveal many weaknesses which might otherwise go unnoticed.

If effective reading is to be realized by our students, it is essential not only that we provide for practice in the general skills involved, but also that we, as teachers, be aware of the different types of reading that students may encounter at the secondary level. Such recognition makes it possible to give more helpful guides to lesson preparation and also to set definite exercises which will call for the use of the skills involved in the particular type of reading. The types of reading encountered by the student on the secondary level have been analyzed as follows:

(1) Reading for comprehension.
(2) Reading for fact-finding.
(3) Reading for retention.
(4) Reading for analysis and evaluation.
(5) Reading for enjoyment.

It is, of course, quite probable that many of the reading assignments in science will involve more than one of the above types. The pupil should be taught to discern these types and employ the specific skills accordingly.

In teaching pupils to read for comprehension, it is essential that they learn to select topic sentences, locate details, and summarize and outline paragraphs read. These skills may be developed by having the learner answer questions about a passage, outline what has been read, or prepare a list of questions answered by the assignment. It may also be helpful to ask pupils to reread a passage consulting dictionaries and other references in getting meaning from troublesome parts. Another suggestion is to have pupils read rapidly through several pages, checking all references to a given law, principle, or theory. Teach the pupil to translate the words of an author into his own words and develop in him the habit of spending as much time in rethinking what he has read as he spends in the actual reading.

Reading for factual information implies reading for details

This may be accomplished by asking the pupil to collect facts from an assignment to support a judgment, about a person, a place, a theory, hypothesis, or law. Another approach may be to ask pupils to find specific answers in the text to definite questions. They may also be asked to find facts that will refute a statement presented. It is also possible for the teacher to give the gist of a certain paragraph and then set the pupils the problem of finding the passage.

Honest and intelligent skimming is often a very great help in reading for factual information. There is a difference between skimming and rapid reading which few pupils make and yet which is very important. Skimming means looking to see what is in a paragraph and deciding quickly whether you want it or not. It is a rapid evaluation of the content. In teaching pupils the art of skimming the following devices may prove helpful:

(1) Ask them to read under the pressure of time and permit them to take notes to be used in discussion.
(2) Teach them to look for topical sentences and key words and phrases.
(3) Ask a question specifically answered in the assignment and see who can first find the passage which answers it.

When an assignment demands reading for retention, pupils may be asked to underline statements that are important, take notes on important aspects or memorize key words and phrases. It is also helpful to have them summarize a given passage or report on it after reading it. Another device is to assign a section or chapter in a book asking the students to skim through it a page or two to the minute and then write down what they have remembered or answer specific questions.

Reading for analysis and evaluation calls into play the ability to discriminate between essential facts and irrelevant material. The pupil may be set the problem of comparing the viewpoints of two or more authors on a certain topic or he may be asked to explain what the author means by certain words or phrases. Another method for developing ability in

this type of reading is to give the point of view of some author on a topic and ask the pupil whether the author of the book they have read on the same topic agrees or disagrees with the stated point of view.

A few suggestions as to how teachers may help pupils avoid reading difficulties are suggested below.

(1) Go slowly and make very sure that pupils understand the work.
(2) See to it that periods devoted to the recognition of new words and symbols are frequent.
(3) Have an ample supply of dictionaries in the room.
(4) Devote periods frequently to having the pupils read aloud from the assignment.
(5) Be sure that the assigned materials are within the range of the student as far as comprehension and vocabulary are concerned.
(6) Provide for use and repetition of new words and symbols.
(7) Select books with good illustrations and teach pupils how to use them.
(8) Teach pupils to rethink passages read.
(9) Select books with adequate indexes, glossaries, and footnotes.
(10) Teach pupils to read thoughtfully and attentively, to question, doubt, approve, disagree, modify, and compare as they read.
(11) Teach pupils how to weed out irrelevant facts and ideas.
(12) Teach pupils to seek relationships in the passages he reads and to associate new ideas with his first experiences.

READING FOR EXACT MEANING [1]

In attacking the problem of reading for exact meaning, an analysis should be made of the mental processes involved in reading. At its upper levels, reading involves most, if not all, of the highest activities of the mind. These activities, psychologically considered, include association, imagery, apperception, attention, reasoning, and comprehension. Comprehension is considered as a distinct process, almost synonymous with interpretation. In the problem under consideration here, it is the end toward which the other processes are directed.

[1] This section is based on Chapter XIV of Gray's *Deficiencies in Reading*. It is used with the permission of the publishers, D. C. Heath and Co., Boston.

Associations which are clear, ready, and accurate are essential to reading for exact meaning. Printed words are symbols. To a child just learning to read, they are a new set of symbols, for he is already familiar with one set of word-symbols, which are oral. To a reader of a few years' experience, the symbols have a confusing way of changing their meanings according to the way they are used with other symbols. The word-symbol "dry," for instance, has no absolute meaning, in spite of what one may find in the dictionary. One reads of a "dry summer," or "He spoke in a dry tone," or "The ship put into dry-dock," or "He is politically dry but privately wet," or "They endured a dry paper on reading." The reader's associations must be prompt and facile if he is to understand exactly the word-symbol which is needed in the particular use under his eye. Naturally, this implies the importance of language experience and training. The associations of word-symbols are made in the visual, auditory, or the kinaesthetic areas. One sees the symbol, one hears it, or one feels it. Naturally, the more times these areas have been stimulated, the richer the meaning which attaches to any word or group of words.

An important aspect of association, and its relation to previous experiences with word-symbols and combinations, is the "feel" for language. It is a kind of automatic hunch system which operates all the time we are reading. It gives us a sense of direction, a foreknowledge of where the words are leading us, and it relieves us of much doubt and labor in testing each word-symbol or group for a variety of meanings before we determine the exact one needed. For example, there are probably few of us who can read Latin this way. We study case endings and word order. If we have recourse to the lexicon, we must sift out the meaning necessary in the particular construction. But our long association with English, our "feel" for it automatically does all this testing for us. William James says that in all thought, and this includes the stream of thought while reading, there are "substantive" parts and "transitive" parts. Our thought and our reading are

processes of getting from one substantive part to another. The transitive parts are feelings of relation.

To illustrate this tendency, as it applies to reading, note the educated adult's ability to read aloud, with proper emphasis, a selection which he sees for the first time. Previous associations with the word-symbols have aroused the proper expectations for their sequence, relative importance, and meaning. In reading for exact meaning, therefore, the value of the ability to anticipate the meaning which is to come in a passage cannot be overemphasized. It not only increases the span of perception, and thereby speeds the rate of reading, but it also puts interpretation on a higher plane. It makes reading a kind of scientific guessing which allows the reader to move forward with fewer cues than would otherwise be necessary. Certain techniques can be used to develop this ability. The completion test, in which the pupil supplies correct words for blank spaces in a selection, is one. This is particularly valuable if connectives are frequently omitted, thereby requiring conscious associations for "transitive parts," to the end of making these associations automatic. Another type of exercise which can be used is one of disarranged sentences. Here the pupil rearranges the words so that they form sentences with meaning. It is interesting that this type of test is used also to detect ability fundamental to composition work. The relation of clear and effective composition to reading for exact meaning will be touched upon in another connection, later in this book.

A second mental activity involved in reading for exact meaning is *imagery*. This is probably the hardest to develop, direct, or control. Imagery, generally, is visual, auditory, motor, or kinaesthetic, and frequently involves a combination.

The dominant imagery varies greatly with individuals. When some persons read, the word-symbols evoke a series of mental pictures; with others, a series of word sounds, or other sounds stimulated by the words. The imagery is of value in itself particularly in narrative reading, with which we are not directly concerned here. In reading for exact meaning, im-

agery must undergo a further translation to intellectual comprehension. In certain types of problem reading, however, particularly those relating to spatial relationships in mathematics, a vivid and well-trained visual imagery is of great importance. It can be developed by "verbal visualization," in which pupils tell the exact space relationships and mental pictures which they see when reading passages in which these relationships are important, and by the use of imagery of all types in stimulating concentration while reading. It should be stated, however, that good comprehension is possible to many people with little of the intermediate step of imagery.

The third mental factor in reading for exact meaning is *apperception.* This is a subjective factor, involving the mind-set which determines the interpretation of word groups encountered in reading. The apperceptive process may be dangerous in some of its workings. Through it, meanings of words may be distorted by preceding words in a series of similar appearance, interesting events of the preceding day, distractions of attention, and so on. It is apperception which causes pupils to read "fraternal rations" for "fraternal relations," "truly Mormons" for "truly enormous" and "the chairman sat in his face" for "the chairman sat in his place." But apperception can be made a staunch ally of exact reading. If the teacher has been careful to set the stage, giving the necessary background of vocabulary, setting, and purpose, apperception will serve to intensify interest and concentration, and thereby to facilitate exact reading. This emphasizes the need for motivation, for reading materials utilizing the approach through interest of the pupil, the wise preparation of the reading situation, and the relation of reading to current experiences of the pupil. One can find in apperception a justification for integrated materials and correlated reading.

A fourth mental factor in reading for exact meaning is *attention.* All mental activity requires effort, and reading is no exception. Many kinds of reading can be done with relatively slight effort, but reading for exact meaning requires a maximum. It is a well-known fact that speed tests for reading

frequently have the effect of improving the pupil's comprehension. The higher degree of attention which the time-stimulus invokes accounts for this. This may be an artificial stimulation, but it is certain that some kind of drive is most efficacious in increasing attention, and thereby comprehension. The pupil should not allow himself to read anything inattentively. All his reading should be upon the efficiency level. For example, pupils often read problems incorrectly because they are so anxious to get at the working of the problem that they disregard the fact that reading is a part, in fact a vital part, of the problem itself. Therefore, the teacher's preparation for the working of problems should direct as much attention to the reading of the problems as to the working of the problems.

Too many children allow attention to fluctuate while reading. Skillful preparation by the teacher for a reading lesson can help to reduce and possibly to eliminate such fluctuations. The setting of the problems to be solved through reading, specific facts to be found, questions to be answered, central ideas to be stated, true and false questions to be filled in, can be used effectively as drives and attention-fixers. In any kind of problem reading or reading for exact meaning, it is the teacher's job to provide such incentives. Through the wise provision of such attention-getting stimuli, the pupils are aided in developing such an individual technique for themselves, adopting the attitude of asking themselves, before they begin reading, "What information do I wish to secure from this selection?" "What are my present ideas about this subject, and how may they be changed?" "If I were reading this selection for an examination, what points should I be on the lookout for?" Consciously or unconsciously, the efficient adult reader does these things. He reads with purpose. It is the teacher's job, first to supply such purposes for the study-type reading, and second, to establish the habit in pupils of setting up purposes for themselves in reading. It is a most powerful stimulus for attention, and attention is a *sine qua non* of reading for exact meaning.

Reasoning is the fifth mental factor in reading for exact meaning. Thorndike's studies of reasoning have led him to emphasize that reading for exact meaning requires that each word produce a correct meaning, that each element of meaning be given a correct value in its relation to others, and that the resulting ideas be examined and tested to make sure that they satisfy the purpose for which the reading was done. This is problem-solving, if you will. It implies a conscious, questioning attention to particular words and word groups, to the end of arriving at the one unmistakable and exact meaning of the passage. It is not at all the kind of process which is implied in the phrase, "He who runs may read." It requires that associations, in regard to word-symbols, be brought into the focus of consciousness. It requires a mental debating of pros and cons of meaning of specific words, and a testing of the final decision against the ultimate sense of the passage and the final purpose of the reading. It is "study-type" reading, and it is the absolute test of whether or not a person really can read. Here, again, the teacher should take the responsibility for setting up a problem to be solved by reading. The actual material of the textbook or other class reading is preferable to any selected and unrelated exercises. The regular class reading takes advantage of the apperceptive accretion, interest, and immediacy. The teacher's way of stating the problem may take a great variety of forms. It may call for a statement of central thought of paragraphs; an outline, partially filled in, or to be done entirely by the pupil; a multiple choice of answers, in which the choices are not misstatements but rather several inexact statements with only one absolutely exact; the writing of a summary paragraph; the selection of key words; the statement of certain facts; the selection of pertinent elements and the rejection of others; the organization of thoughts according to the purposes for which the reading was done; the finding of details with which to support or refute statements made by pupils or the teacher; and others. In this study-type reading, involving reasoning and all that it implies, the teacher should emphasize that the

pupil should spend at least as much time thinking about what he reads as in the actual reading itself. Almost always such reading, with the accompanying problem-solving, suggests, or rather demands an oral discussion after all the returns have been filed. This affords an opportunity for bringing to the attention of the whole class the exact meaning of each portion of the reading, through volunteering by pupils, and thus to exercise the powerful incentives of commendation and reward for virtue.

The sixth factor in reading for exact meaning, and the summation of all other factors is *comprehension.* In the type of reading here considered, comprehension frequently takes the form of interpretation, that is putting to one's individual use, and one's habitual modes of thought and expression the meaning gleaned from the reading. The word "expression" is used with a particular purpose in the last statement. Benedetto Croce, the Italian philosopher, has a theory of knowledge which states that one does not *know* that which one cannot *express.* A perennial excuse of a pupil, when asked to state the meaning of a passage of reading, is "I know what it means but I can't say it." According to Croce, the pupil doesn't really know it and there's many a teacher who shares this point of view. Previously in this chapter there was mention of the relation between effective composition ability and the ability to read for exact meaning. In general, the pupil who reads most accurately is the one who expresses himself in writing most clearly. There is great value in asking for paragraph summaries of reading, in paraphrasing of difficult passages, in supplying concrete examples for abstractions encountered in reading, in writing headlines or topic sentences, and in writing paragraph summaries. Many times the oral interpretation of passages or minute-summaries of a chapter, can be used effectively to stimulate reading for comprehension. Above all the teacher should stress the necessity for complete transmutation of the meaning of the reading into the thought and wording of the pupil. A mere parroting of phraseology in the text is inadequate. The meaning must go through the

distillation of the reader's own thought, become completely translated into idea and perception, and emerge in the words of the reader's own natural expression. This type of class exercise should again be used with the object of making a similar process habitual with the reader, when left to his own devices. He should be encouraged to pause from time to time in his reading to state to himself in his own words the meaning or gist of that which he has just read. And when he takes notes upon reading, he should be urged to make the expression of these notes his own.

Efficient comprehension, then, requires a wide span of perception and the ability to observe. There must be familiarity with language relations, a rich background of experience, a controlled system of imagery, unwavering attention, and evaluation of ideas. Thus can be attained that degree of interpretation and expression in the reader's own idiom which is essential to reading for exact meaning.

THE EFFECTIVE USE OF SOURCE MATERIALS. Books are among the most important sources of material used in solving science problems. In some places where library facilities are poor, this source may be confined to the textbook and perhaps a general reference such as an encyclopedia. In other cases the library is the heart of the school. In either case it is important that pupils learn good techniques for locating materials. Where there is a trained librarian the science teacher may work in close coöperation and perhaps provide time from the science class for the librarian to give instruction and help. In places where there is no school librarian, it may be possible to call in the town librarian. It may be necessary in some instances for the science teacher herself to give the needed instruction.

The pupil should be made to realize early in his science experience that books are tools and they must be used skillfully if the best results are to be attained with them. It is important that instruction be given in the parts that make up a book. The table of contents is an outline of the book and is used for locating specific chapters or subtopics. The bold-

faced type used throughout a chapter is an outline of th chapter and has many important uses. Pupils should be taugh the use of illustrations such as pictures, graphs, and tables These are amplifiers of the text and often add precisioı and form to the mental image derived from reading th text.

It is important in the solution of a problem that pupil learn how to pick out key words in the problem that may lea to information bearing on its solution. This selection of ke words will call for instruction in the use of book indexes an the selection of proper subtopics within the index. The write has found even in the seventh grade that some pupils are un able to handle alphabetized materials with efficiency. Youn people may go through an entire year with a textbook withou discovering that there is a glossary or an appendix in the bool or learning how these may be helpful to him in securing evi dence. The use of the dictionary or glossary may be moti vated by having pupils read parts of the assignment aloud They are almost certain to stumble over pronunciations or t lack an understanding of certain terms. These, then, becom real needs and the dictionary, glossary, or footnote may b pointed out as an aid for use. The use of these devices mus be fixed as habits.

Other devices such as cross references, running headings marginal headings, and bibliographies should be pointed ou to the pupil and instruction should be given in their prope usage. For example, chapter or appendix bibliographies of ten furnish valuable leads for additional information on a problem under investigation.

In the use of a text or reference book, it is also importan that marks of emphasis used by the publisher are called t the student's attention. These may be devices such as bold faced type, italics, and underlining. If books are purchased o owned by the student, it may be well to encourage him t develop his own scheme of marking important ideas or pas sages by marginal notes, underlining, or some other device Where books do not belong to the student, it may be wise t

have him take notes from the reference bearing on the solution of his problem.

Securing information on a given problem may call for the use of other devices such as handbooks, identification keys, magazines, newspapers, pamphlets, bulletins, catalogues, etc. The teacher should see that whenever such devices are called for the students are given adequate instruction and practice in their use.

It is essential that students be instructed in the plan, arrangement, and proper use of library facilities. It has been the experience of the writer that much valuable time is wasted because young people use a trial-and-error method in locating library materials. Early in his school experience he should be taught the use of the card index, the *Readers' Guide*, general references, bound magazines, and other essential features of the library. The instruction in the use of these devices can probably be done most effectively by a trained librarian but the teacher may coöperate by proposing library assignments which will force the students to use them and so to become more proficient in locating materials.

Reliable Sources of Information. The solution of problems both in school and out demands that the information upon which hypotheses and conclusions are based must be accurate. We are living in a period when through the radio, the newspaper, and other agencies we are likely to be flooded with spurious advertising and unreliable information. The purpose of this section is to suggest some of the sources from which one may secure technical information which can be depended upon.

There are many organizations and institutions which furnish dependable materials, either free or for a very small cost, bearing on problems in science. A listing of some of these sources will be found on page 90. These agencies include departments and bureaus of the federal and state governments, scientific societies, and certain large corporations and industries which have high ideals of service. Museums, zoölogical gardens, botanical gardens, city aquariums, and city plan-

etariums are sources of information. In recent years several consumer organizations which maintain testing laboratories have been set up. These organizations supply confidential information on various materials and products to subscribers.

The library is also a source of reliable information available to a large number of communities. In using books and pamphlets as sources of information, it is essential that one be careful in selecting. Not all that is printed is reliable. One should always look at the title page and check the author. What degrees does he have? Is he a recognized expert on the subject about which he is writing? It is also important to check the date of publication of the book. Science and engineering are moving forward at such a rapid rate that a book published even five years ago on some scientific subjects may be out of date today.

In attempting to get information on a problem, the opportunities of the local community should be kept in mind. In almost every locality there are experts on certain subjects. The local doctor, dentist, hospital, health officer, and water commissioner can supply information on health. Service station attendants, garage mechanics, etc., can give information about your car. The local stores will no doubt have pamphlets which, if dependable, may give information that will be helpful. Get in touch with your nearest library, and the librarian will usually help locate sources of material.

SOURCES OF RELIABLE INFORMATION

1. Commercial Agencies.
    1. American Gas Association, 420 Lexington Ave., New York.
    2. Bell Telephone Laboratories, West St., New York.
    3. General Electric Co., Schenectady, N. Y.
    4. General Motors Corporation, Research Division, Detroit, Mich.
    5. Ford Motor Company, Detroit, Mich.
    6. Metropolitan Life Insurance Co., New York.
    7. Western Electric Company, Pittsburg, Pa.
    8. The Borden Company, New York.
    9. Bausch and Lomb, Rochester, N. Y.
    10. Taylor Instrument Co., Rochester, N. Y.
    11. Eastman Kodak Company, Rochester, N. Y.

12. American Petroleum Institute, 50 West 50th St., New York.
13. National Conservation Bureau, 60 John St., New York. Material on accident prevention.

2. CONSUMERS AGENCIES.
   1. Consumers Council Division, Agriculture Adjustment Administration, United States Department of Agriculture, Washington, D. C.; Issues *Consumers Guide* twice monthly. (Monthly—June, July, August, Sept.)
   2. Consumers Research Inc., Washington, N. J. Supplies confidential information to subscribers.
   3. Consumers Union, 55 Vandam St., New York. Issues a monthly report to subscribers and publishes an Annual *Buyers Guide.*
   4. League of Women Shoppers, 220 Fifth Ave., New York. Economic information only.
   5. Household Finance Corporation, 919 N. Michigan Ave., Chicago. Better Buymanship Bulletins.
   6. Inter-Mountain Consumer's Service, Denver, Col.
3. FEDERAL AND STATE AGENCIES.

The Federal Government maintains many bureaus and departments which publish reliable materials bearing on the solution of many science problems. A complete listing of the publications of these bureaus and departments may be secured from the Superintendent of Documents, Washington, D. C.

The Department of Agriculture maintains several bureaus which are listed below:

Bureau of Animal Industry. Studies diseases of animals and how to combat them.

Bureau of Biological Survey. Studies the distribution of plant and animal life over the country. Publishes many bulletins.

Bureau of Entomology. Studies insects and ways of combating and exterminating harmful ones.

Bureau of Fisheries. Bulletins on fish and fisheries.

Forest Service. Publishes materials on conservation and the use of forest products.

Federal Horticulture Board. Has charge of quarantine on plant diseases.

Office of Experiment Stations. Has control over Agricultural Experiment Stations in the several states. Issues many useful bulletins.

Bureau of Home Economics. Issues useful bulletins on many subjects.

The Insecticide and Fungicide Board. Studies the best methods of destroying plant and insect pests.

Other Government Agencies.

Bureau of Mines. Materials on mines and mining.

Bureau of Standards. Issues bulletins on weights, measures, materials, machines, etc. The Government Testing Bureau.

National Observatory. Issues materials related to astronomy.

National Parks Service. Issues many valuable pamphlets on conservation and on the National Parks and National Monuments.

Public Health Service. Issues material related to public health.

Weather Bureau. Issues weather maps and summaries of weather data and climate.

The National Resources Commission. Send for list of publications.

The Office of Education in its monthly publication "School Life" ($1.50 per year) prints lists of new government publications of interest to teachers, including those of other bureaus.

State Bureaus and Agencies.

State Department of Health
State Department of Highways
State Department of Agriculture
State Department of Mines
State Department of Fisheries
State Department of Forests and Waters

4. MAGAZINES.
    1. *National Geographic Magazine*, National Geographic Society, Washington, D. C.
    2. *Hygeia*, American Medical Association, Chicago.
    3. *The Nature Magazine*, American Nature Study Society, 1214 Sixteenth St., N. W., Washington, D. C.
    4. *American Forestry*, American Forestry Association, 919 17th St., N. W., Washington, D. C.
    5. *Bird Lore*, National Association of Audubon Societies, 1006 Fifth Ave., New York.
    6. *The Scientific Monthly*, Scientific Monthly Publishing Co., Lancaster, Pa.
    7. *The Science News Letter*, Science Service, Washington, D. C.
    8. *The Scientific American*, Scientific American Publishing Co., New York.
    9. *Natural History*, American Museum of Natural History, New York.
    10. *Popular Astronomy*, American Astronomical Society, Princeton, N. J.
    11. *Survey*, 112 E. 19th Street, New York.
5. MUSEUMS AND PLANETARIUMS, AQUARIUMS, ZOOLOGICAL AND BOTANICAL GARDENS.
    1. American Museum of Natural History, New York.
    2. Field Museum of Natural History, Chicago.
    3. National Museum, Washington, D. C.
    4. Adler Planetarium, Chicago.
    5. Hayden Planetarium, New York.

6. New York Zoological Society, New York.
7. The Aquarium, New York.
8. Shedd Aquarium, Chicago.
9. St. Louis Zoological Garden, St. Louis, Mo.
10. Missouri Botanical Gardens, St. Louis, Mo.
11. National Zoological Gardens, Washington, D. C.
12. Franklin Museum, Philadelphia, Pa.
13. Museum of Science and Industry, Rockefeller Center, New York.
14. Museum of Science and Industry, Chicago.
15. Carnegie Institute Museum, Washington, D. C.
16. New York Botanical Gardens, New York.
17. Brooklyn Botanical Gardens, Brooklyn, N. Y.

6. ORGANIZATIONS.
1. Academy of Natural Sciences, Logan Square, Philadelphia, Pa.
2. American Association for the Advancement of Science, Smithsonian Institute, Washington, D. C.
3. American Astronomical Society, Princeton Observatory, Princeton, N. J.
4. American Chemical Society, Mills Bldg., Washington, D. C.
5. American Eugenics Society, 185 Church St., New Haven, Conn.
6. American Forestry Association, 919–17th St., Washington, D. C.
7. American Civic and Planning Association, Union Trust Bldg., Washington, D. C.
8. American Ornithologists Union, University of Michigan, Ann Arbor, Mich.
9. American Nature Association, 1214 Sixteenth St., N. W., Washington, D. C.
10. American Wild Life Institute, Investment Bldg., Washington, D. C.
11. American Home Economics Association, 620 Mills Bldg., Washington; D. C.
12. American Medical Association, 535 N. Dearborn St., Chicago.
13. Charles Lathrop Pack, Forestry Foundation, 1214 Sixteenth St., N. W., Washington, D. C.
14. The Engineering Foundation, 29 W. 39th St., New York.
15. Ecological Society of America, Northwestern University, Evanston, Ill.
16. Educational Conservation Society, 43–13 Laurel Hill Blvd., Woodside, Long Island, N. Y.
17. Emergency Conservation Committee, 734 Lexington Ave., New York.
18. Garden Clubs of America, 598 Madison Ave., New York.
19. International Committee for Bird Preservation, T. Gilbert Pierson, 1006 Fifth Ave., New York.

20. Isaak Walton League of America, Merchandise Mart, Chicago.
21. National Academy of Science, Washington, D. C.
22. National Association of Audubon Societies, 1006 Fifth Ave., New York.
23. National Board of Fire Underwriters, 85 John St., New York.
24. National Geographic Society, 16th and M St., Washington, D. C.
25. National Parks Association, 1624 H St., N. W., Washington, D. C.
26. National Research Council, Washington, D. C.
27. Science Service, 2101 Constitution Ave., Washington, D. C.
28. Smithsonian Institute, Washington, D. C. Material on all science subjects.
29. Underwriters Laboratories, 207 E. Ohio St., Chicago.
30. American Social Hygiene Association, 50 West 50th St., New York.
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Chapter VII

The Evaluation of Learning in Science

THE PLACE OF EVALUATION IN SCIENCE TEACHING

THERE is probably no aspect of instruction in the secondary-school curriculum today that is changing as rapidly as the evaluation of learning products. The changing philosophy of the secondary-school curriculum is shifting the emphasis of evaluation away from the exact measurement of mastery of content in a given area, as the only index of achievement, toward an attempt to evaluate other outcomes, such as aspects of thinking and desirable attitudes.

Guided by philosophies similar to the one set forth in Chapter I, the function of instruction in the modern school is gradually shifting away from the content-centered curriculum toward a vitalized, life-problem-centered type of procedure. This does not imply that content is mastered to any less degree but rather suggests a shift from content mastered as an end in itself to content mastered as a means of solving problems.

It is quite obvious that the appraisal of the growth of an individual toward goals which have been set on the basis of his life needs and interests, is a far more subtle and involved task than measuring the degree to which a student has mastered the facts of biology or chemistry.

Evaluation as such cannot be separated from the other fundamental aspects of the curriculum, namely the educational goals and the instruction. Curriculum workers in the past have done a minute job of determining goals in an objective manner but often have left the evaluation of growth toward these goals to the specialists in the various subject-matter areas. The only type of evaluation program that can reveal the growth of a student toward certain goals is one in which the instruments of evaluation have been set up on the basis of the objectives or goals of the course.

An evaluation program which would attempt a complete

appraisal of a student's growth in science or any other subject area has several obligations: first, to devise tests and measures that will reveal not only the mastery of facts and principles of a given area, but a functional understanding of the concepts and generalizations involved; and secondly, to devise techniques for revealing growth in certain other outcomes such as the elements of reflective thinking, attitudes, creativeness, personal interest, and social sensitivity.

A further obligation of an adequate evaluation program, equally as important as the appraisal of achievement, is that of detecting as early as possible the strengths and weaknesses of students with respect to the objectives or goals of the course. Evaluation instruments must have the property of diagnosis, if there is to be any effort made to have students proceed at a rate commensurate with their ability.

EVALUATING GROWTH IN MASTERY OF KNOWLEDGES.

Even though there has been a rapid development in the past few years in the direction of evaluating outcomes of science teaching other than mastery of content, this objective is still important and no doubt will continue to be. The fault in the past has been that content mastery was the only outcome indicated, and pupil growth in a subject area was determined on this single aspect.

When problems are solved by young people in science, it is essential that they come out with mastery of certain facts and principles or an enlarged understanding of a science generalization. These knowledges must be evaluated, for they are an important aspect of the total growth of the student in a given science area. Exact thinking demands mastered facts and principles, and this mastery may be evaluated by the application of techniques which have been developed through the many available subject-matter tests over the past twenty-five years.

While it is important as a measure of growth in knowledge outcomes to give end-of-semester or end-of-year mastery tests, it is generally thought that the principal function of such

measures is for instructional purposes. Mastery should be tested during the year at frequent intervals to enable the teacher to judge the completeness of learning and to be in a better position to prescribe remedial work, while there is still an opportunity to do something about it. When the evaluation of mastery is left to the end of the year there is little that can be done for the pupils who show weaknesses. A frequent testing program is a stimulus both to teacher and pupils.

At the present time there are many end-of-year and also unit tests on the market covering the several areas of science teaching. It is quite common now to find textbooks accompanied by unit-testing programs either included in workbooks or separately. This seems to be a move in the right direction. With the shift of emphasis away from logically organized courses in the high-school sciences toward courses where content is organized around problems of pupil adjustment, there may be less demand for instructional tests based on units and chapters of textbooks and an increased demand for teachers who are using a certain problem organization to build their own mastery tests. Such a procedure, of course, will not alter the validity of techniques now used, but will mean simply a different organization of test items.

A study of available mastery tests in the sciences will reveal several acceptable testing techniques in use. Many of these techniques are adapted only to the evaluation of fact acquisition, although some may be used for testing the understanding of generalizations or even the application of principles. The techniques developed by Tyler for evaluating outcomes of reflective thinking seem to have considerable promise for application in the area of content mastery as well. At the present time there is great need for tests designed to evaluate the mastery of laboratory techniques and procedures.

A common mistake in the use of all evaluation instruments in high-school science is to apply the tests only at the close of a unit of instruction and then to assume that the perform-

ance on the test reveals growth. This may or may not be the case. To reveal the results of instruction in a given learning period it is essential that a pre-test be given before the instruction and a mastery test following the instruction. The difference in performance on these tests will be a more reliable index of student growth in the outcome being tested.

The various techniques used for testing mastery in science such as completion, one-word answer, true-false, multiple choice, etc., have been fully and adequately treated in other books and therefore the authors have deemed it wise to devote more space to the discussion of some of the newer techniques designed to evaluate certain of the other outcomes of science teaching. A full and complete listing of available tests for the various high-school sciences and the publishers will be found at the end of this chapter.

THE EVALUATION OF OTHER ASPECTS OF GROWTH.

It has only been within the past few years that any attempt has been made to evaluate such aspects of growth as the elements of reflective thinking, scientific attitudes, resourcefulness, creativeness, social sensitivity, etc. The area of science as a subject has had as much or more attention by test builders in these aspects of growth than any other area of the curriculum. It is therefore appropriate that the remainder of this chapter be devoted to a consideration of some of the tests and techniques which these workers have produced for science teachers.

Among the contributions to the literature of this aspect of evaluation with particular reference to science must be mentioned the work of Curtis, Davis, Tyler, Raths, Frutchey, Hendricks, Heil, Horton, and Zechiel. There have been other contributors, but to these belong the credit for pioneering and developing the materials and techniques which are now recognized as fairly standard.

The number and diversity of instruments available for evaluation in the field of science makes the problem of understanding the materials a difficult one. There are tests on the

interpretation of data, setting hypotheses, skills and techniques, application of principles, nature of proof, scales of belief, and many others. Also the techniques developed are varied and unique. It is the plan of this survey to take the different phases of the subject, one at a time, and discuss those materials and techniques which have been developed.

Discovering and Defining Problems. An appraisal of the abilities involved in this aspect of problem solving may be attacked in several ways.

1. *The Anecdotal Record.* This method consists of recording the specific situation and then describing, as exactly as possible, the behavior characteristics of the student in the situation. For example: In a class discussion of some data collected to show the effects of air and wall temperature on the comfort of a person in a room, one student asked, "How do you explain the apparent fact that a person in a room where air temperature is 85 degrees Fahrenheit is cold when the wall temperature is 50 degrees Fahrenheit?" This situation was typical of what the teacher meant by "sensitivity" to a problem in physics and the incident was recorded by a brief note at the time.

Obviously, this is a time-consuming process and therefore certain classroom short-cuts have been devised to simplify it. For example, a note may be made in the classroom that a certain student evidenced a sensitivity to a problem in physics class during a certain period, with whatever other data is essential. At the close of the period, then, a more detailed account may be written.

Another shorthand procedure has been devised in which the names of students are placed down one side of a sheet and the abilities under observation across the top. The paper is then divided into squares by lines. This provides a square for each ability opposite each name. The presence or absence of the desired response may be recorded by means of plus and minus signs. In some schools the anecdotal technique has been developed to the point of providing dictaphones so teachers may supplement their classroom notes with a minimum of effort.

There are many opportunities in science to record observations of behavior related to the discovery and definition of problems: in the laboratory, in class discussion, on field trips, etc. Frutchey and Tyler [1] describe one such situation from a biology class on a field trip as follows:

"On a recent field trip in the spring the pupils in a biology class saw a number of forsythia blossoms in full bloom. As it happened, all of the blossoms were on the lower branches of the bushes; none had developed on the upper branches. Several of the students noted this fact, but only two raised the question, 'Why are all the blossoms on the lower branches?' . . . One of the students carried his question still further. 'Are all forsythia blossoms on lower branches? Have the lower branches been protected from the recent cold weather?' This illustrates the ability to define some of the more specific questions which need to be answered in order to solve the more general problem."

The principal difficulty of the anecdotal record technique is one of carefully defining in advance the desirable or undesirable student behavior. Unless the teacher uses extreme care in making the expected behavior explicit in his own mind, very often irrelevant evidence is obtained and many relevant situations are missed. Another pitfall of the anecdotal record technique is that often a teacher tries to use it to gather evidence concerning pupil achievement in too many objectives. It has been found that five or six different specific behaviors to be watched for is the maximum addition which can be made to the routine teaching duties.

2. *The Essay Type.* The more usual type of essay question, with specified situations, may be also used to secure evidence of the students' ability to discover and define problems. The following situation [2] illustrates how a question may be directed to obtain such evidence:

"A farmer has a flock of chickens. He noticed that some

[1] Frutchey, Fred, and Tyler, Ralph, *Examinations in the Natural Sciences. The Construction and Use of Achievement Examinations.* Houghton Mifflin Co., Boston, 1936, p. 235.

[2] *Ibid.*

days he would get many eggs and on other days he would get very few eggs. What information must you have before you can tell why there was a difference?"

The training of young people in the ability to define problems and the evaluation of their achievement may go along together. For example, after a unit or topic for investigation has been selected, the teacher may plan an activity in which an over-view of the unit is given. This may be in the form of a mimeographed introduction, a talk by the teacher, or even informal discussion with the group. The students may then be instructed, as an assignment, to bring in the questions or problems growing out of the activity. The range and quality of the problems proposed will give a rough measure of the student's sensitivity to problems as well as his ability to define problems.

3. *The Mixed Response.* Frutchey and Tyler [1] suggest still another way in which some indication of this ability may be obtained. In this technique the statement of a broad problem is followed with a list of minor questions or problems which must be solved. Mixed in with the relevant questions are some which might be associated with the major problem but which do not bear directly upon it. The students are asked to check the problems in the list which must be answered before the major problem can be solved. Again this is not only a device that may be used for evaluation, but for instruction as well.

Collecting Information Bearing on the Solution of a Problem. This step in solving problems involves a large group of fundamental skills which are ordinarily considered to be outside the concern of the science teacher. That the science teacher must be concerned with certain of those skills basic to obtaining information bearing on problems is obvious when one considers, for example, that a large part of the students' information comes from reading. Among the skills involved is the use of the library and reference books as well as the specific reading skills. Accordingly, the science teacher must

[1] *Ibid.*

assume responsibility for providing remedial instruction in those skills when they do not require the attention of a special teacher. In assuming this responsibility, he should take advantage of those instruments of evaluation which will discover most effectively the specific causes of difficulties.

The limitations of space will not permit a detailed discussion of the tests available for evaluating the several special abilities involved. It should be noted, however, that several of the general tests such as the Iowa Placement Examinations contain sections devoted to reading abilities in science.

Several rather simple techniques may be used by the science teacher to discover certain fundamental difficulties in reading. This is especially true of the younger boys and girls studying general science. Individuals may be asked to read aloud during a supervised study period. Often this will reveal the word readers as contrasted with those who read ideas. Another way to discover the slow readers is to start everyone reading a given passage and time them. Comprehension may be roughly evaluated by following a period of concentrated reading with a group of test questions based on the passage read.

Many students experience great difficulty with the vocabulary of science. Single tests on the definition of new words in reading passages will serve not only to keep students alert to the use of glossaries and the dictionary, but will sort out the words which are causing the greatest difficulty and enable the teacher to give special instruction on them.

The efficient use of books and library facilities makes for much more effective problem solving. The test, "The Use of the Library for High School," [1] by Reed is probably the best instrument available at present for evaluating the techniques and skills involved. The familiarity with reliable sources of information has been considered by many teachers as an important element in developing problem-solving abil-

[1] Reed, Lulu R., Test on "The Use of the Library for High School." Bureau of Educational Research, Ohio State University, Columbus, Ohio.

ity in young people. Frutchey and Tyler [1] have worked out and described a way for collecting data on this point. A list of questions such as the following is prepared:

(1) "Where could you find out about the general principles which help to explain the methods of sending pictures by wire?"
(2) "Where could you determine the relative electrical conductivity of iron, copper, and aluminum?"
(3) "If you were making a special report on the corpuscular theory of light, where would you get helpful information?"

In response to these questions it is expected that the student will be as definite as possible, mentioning the names or titles of books, magazines, newspapers. If the student is unable to be so specific as to give these, he is asked to tell how he would locate the book, magazine, or newspaper which contained the information.

It is essential that students learn to evaluate their sources of information. The Science Committee of the Wisconsin Education Association [2] has prepared a series of tests for evaluating this aspect of problem solving in general science, biology, physics, and chemistry. The tests are made up of a series of items from each field "which represent beliefs, opinions, and facts which either are, or once were, accepted as being true." The individual is asked to judge each of these items as belonging to one of the following stages in the development of exact knowledge:

(1) Superstitious belief stage.
(2) Authoritative opinion stage.
(3) Observation stage.
(4) Controlled experimentation stage.

Certain kinds of information in problem solving must be collected by observation and experiment. Students vary greatly in their ability to observe accurately, and many teachers consider this ability an important outcome to be

[1] *Op. cit.*, p. 232.

[2] Science Committee of the Wisconsin Education Association, Insurance Building, Madison, Wis.

evaluated. Even a small amount of training in this skill will produce measurable results. It is not essential that exact instruments of evaluation be used for this, since the chief purpose is diagnosis for subsequent remedial instruction. In the Biology Department of the Central High School of Tulsa, Oklahoma, demonstrations followed by mimeographed sets of "best answer" questions have been used both for purposes of evaluating and developing the ability to observe accurately.

The anecdotal method may again be used in recording information on the ability to observe. Data obtained on field trips, in the laboratory, and from other sources may well be noted in such a record.

The Science Committee of the Wisconsin Education Association[1] has developed a test of "Controlled Experimentation" in which a series of experimental problems are described with respect to the factors involved. The student is asked to check in each case which factors were varied, which were kept constant, and which produced the observed difference.

INTERPRETING EVIDENCE AND DRAWING INFERENCES IN THE SOLUTION OF PROBLEMS. The evaluation of the ability to interpret data has been given careful study by the Evaluation Staff of the Commission on the Relation of School and College.[2] The results of their studies seem to indicate that the student achievement in the ability to interpret data depends upon his knowledge of certain principles involved. These may be stated as follows:

(1) "An interpretation can be made from the data without qualification, when it involves an accurate comparison of two or more points in the data."

(2) "An interpretation involving a calculation that can be made directly from the data can be supported or contradicted by the data alone, depending upon the accuracy of the calculations."

[1] *Ibid.*

[2] Evaluation Staff of the Commission on the Relation of School and College of the Progressive Education Association, The University of Chicago, 6010 Dorchester Avenue, Chicago.

(3) "An interpretation going slightly beyond the data, but in agreement with the trend and must be qualified as 'probably true.'" (Extrapolation)

(4) "An interpretation going beyond the data and contrary to the trend revealed must be qualified as 'probably false.'"

(5) "An interpretation referring to a point within the data, but not specifically described must be qualified as 'probably true' or 'probably false,' depending upon whether it does or does not agree with the revealed trend." (Interpolation)

(6) "An interpretation going beyond the data in assuming that things, conditions, processes, and so forth, which are alike in some ways, are alike in others must be qualified as being based upon 'insufficient evidence.'"

(7) "An interpretation assuming the presence of a predetermined plan in nature or purpose must be qualified as being based upon 'insufficient evidence.'"

(8) "An interpretation assigning a cause to the relationships revealed by the data, and when not supported by other evidence, must be qualified as being based upon 'insufficient evidence.'"

(9) "An interpretation involving an ambiguous use or misuse of a term in the data, must be qualified by relating it to the specific 'new' use."

(10) "An interpretation assuming that what is true of a single case, or of a few cases, is true of all cases, must be qualified as being based on 'insufficient evidence.'"

(11) "An interpretation involving a personal judgment, sometimes biased, at other times unbiased, which is external to the data, must be qualified as being based upon 'insufficient evidence.'"

(12) "An interpretation representing a universal generalization, concerning which the data presented serve only as a single illustration must be qualified as being based upon 'insufficient evidence.'"

Horton [1] working at Ohio State University, analyzed into ten types the responses made by students on interpreting data. Such an analysis of student responses is extremely useful for setting situations in the classroom for further instruction and practice in the abilities involved in interpreting data. His analysis is given below:

[1] Horton, Clark, *A Comprehensive Testing Program for Biology.* Doctor's Dissertation unpublished, Ohio State University, Columbus, Ohio, 1937.

Classification of student responses:

(1) Interpretations supported by the data.
(2) Interpretations contradicted by the data.
(3) Unwarranted extensions of the data by interpolation or extrapolation.
(4) Teleological explanations.
(5) Unwarranted conclusions as to cause and effect.
(6) Interpreting multiple effects as cause and effect.
(7) Unwarranted interpretations but go beyond the data given.
(8) Repetition of data without drawing significant inferences.
(9) Valid inferences using only part of the data.
(10) Valid inferences based on all the data.

The following examples represent situations in a test on "Interpretation of Data,"[1] devised by the Evaluation Staff of the Commission on the Relation of School and College.[2]

Directions: A test, an experiment, or a situation is indicated in each of the following exercises. Below the description is a list of several statements, suggested as possible interpretations of the data. Assume that the statements are accurate. Carefully consider each of them and indicate whether you believe that the evidence:

(1) Is sufficient to make the statement true.
(2) Suggests that the statement is probably true.
(3) Is insufficient to make a decision concerning the statement.
(4) Suggests that the statement is probably false.
(5) Is sufficient to make the statement false.

Sample No. 1:

Professor Arthur Hershey of McPherson College has carried on some interesting experiments concerning the survival of white rats in various types of atmospheres. Ordinary air has the following composition:

Nitrogen	77.87%
Oxygen	20.94%
Argon	.94%
Water vapor	.22%
Carbon dioxide	.03%
Traces of helium, xenon, and krypton	

Professor Hershey varied the percentages of oxygen and nitrogen as well as the other gases present in our atmosphere

[1] P. E. A., *Test on Interpretation of Data.* [2] *Op. cit.*

and noted the reaction of the rats in the artificial atmosphere. The following are his observations:

(a) Ordinary percentage of oxygen and nitrogen with other gases missing—supported the life of the rat only a few days.
(b) Pure oxygen, no other gases present—supported life from two to five days.
(c) Ordinary composition with helium replacing nitrogen—supported life in a manner similar to ordinary air.
(d) Ordinary composition with argon replacing nitrogen—supported life only a few days.
(e) A 25% oxygen, 75% argon mixture with all other gases missing—supported life better than the ordinary atmosphere, the rats seemed to be more energetic and apparently suffered no ill effects.

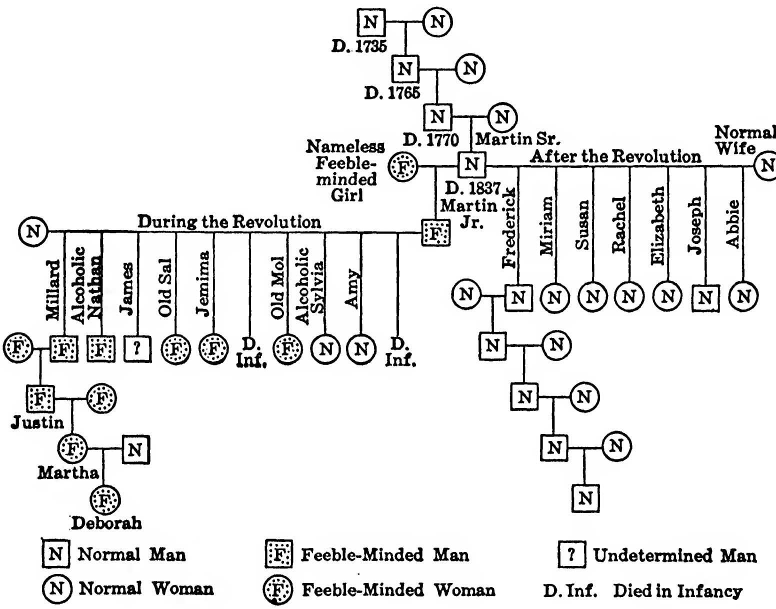
Statements:

(1) When exposed to an atmosphere which contained no nitrogen, a gas which makes up almost 80% of ordinary air, the rats were more active than in ordinary air and apparently suffered no ill effects.
(2) Carbon dioxide and traces of helium, xenon, and krypton were necessary for the existence of the white rats.
(3) The percentage of the gases present in the atmosphere is not the most important atmospheric factor in maintaining the life of the rats.
(4) People should not subject white rats to conditions other than those which nature intended for them.
(5) The white rats died within two to five days in an atmosphere of pure oxygen due to the fact that oxidation occurred at such a rapid rate that tissues were consumed.
(6) Nitrogen must be present in the atmosphere if white rats are to survive.
(7) Professor Hershey performed these experiments in order to see if he could suggest a better atmosphere for human beings.
(8) Human beings, just as white rats, would be more energetic and suffer no ill effects if placed in an atmosphere of 25% oxygen and 75% argon.
(9) When rats are subjected to an atmosphere of ordinary composition, but containing a high percentage of water vapor, they are less active than when the atmosphere contains a comparatively small percentage of water vapor,

(10) Gases present in the ordinary atmosphere in very small percentages play an important part in the maintenance of life in white rats.

Sample No. 2:

In the chart below some data concerning feeble-mindedness are presented:



Statements:

(1) The mating of Martin, Sr. with a nameless feeble-minded girl during the Revolution resulted in a line in which the children were predominantly feeble-minded.

(2) Martin, Sr.'s marriage to a normal woman after the Revolution resulted in a line in which there were several feeble-minded children.

(3) When a normal person marries a feeble-minded person, a large proportion of the children may be feeble-minded.

(4) A large proportion of the children born when two normal people marry may be feeble-minded.

(5) Just as feeble-minded children may be born when a normal person marries a feeble-minded person, so will children born in families in which the parents are drunkards be alcoholics in the greater proportion of such marriages.

(6) About four times as many feeble-minded as normal children were born in the line which resulted from Martin, Sr.'s marriage to the nameless feeble-minded girl.
(7) Feeble-mindedness is solely due to inheritance from parents.
(8) The children born in the line which resulted from the marriage of Martin, Sr. to a normal woman became outstanding leaders in community affairs.
(9) Feeble-minded persons tend to marry feeble-minded persons, and normal persons tend to marry normal persons.
(10) The birth of feeble-minded persons is not beneficial to society.
(11) Had the children who died in infancy lived, they would have been normal men or women.
(12) If Jemima, feeble-minded daughter of Martin, Jr. and a normal woman, had married a normal man, none of their children would have been feeble-minded.

A test made up of problems like the samples cited above is valuable for instructional purposes as well as for measuring student achievement in the ability. For such tests the Evaluation Staff of the Commission on the Relation of School and College have worked out a summary and tabulation sheet.[1] From this summary of a student's performance on a test of "Interpretation of Data," it is possible to get the following information:

(1) His general accuracy in judging the interpretations in the test.
(2) His general accuracy in judging only those statements which must be qualified as probably true or probably false.
(3) His general accuracy in recognizing only those statements which in reality have insufficient data to support them.
(4) His general accuracy in recognizing only those statements which are obviously true or obviously false.
(5) His general tendency to err in the direction of understatement.
(6) His general tendency to go beyond the data.
(7) His general tendency to make crude errors in judgment.

If a teacher has such evidence before him on any particular student, it is possible to plan with that student a program of effective remedial work. There is a psychological factor in-

[1] Evaluation Staff of the Commission on the Relation of School and College, *Interpretation of Data. Explanation of the Summary Sheet and Tabulation Sheet.* P. E. A. 2761, Test 2.5, 6010 Dorchester Avenue, Chicago, Ill.

volved in learning which follows a diagnostic test. The student is usually pent up with the desire to improve his performance and is thus possessed of a drive not usually present in the classroom situation.

Sample No. 3:[1]

Another form of the test on "Interpretation of Data" in which only three types of responses are expected is illustrated by the following problems:

Directions: In each of the following exercises, an experiment is described. Below the description of the experiment are several statements which have been suggested as interpretations of the experiment. Assume that the facts given in the description of the experiment and in the results obtained are correct, then on the basis of *these facts only*, consider each statement.

Mark with an R—every statement which is a reasonable interpretation of the results obtained.
U—every statement which might possibly be true but for which insufficient facts are given to justify the interpretation.
F—every statement which cannot be true because it is contradicted by the results obtained in the experiment.

In an experiment some white starch was treated with brown iodine solution. This was done ten times, and each time a blue color was formed.

Later some white starch was mixed with saliva. The mixture was left for a time and then treated with brown iodine solution. This was done ten times and each time no blue color was formed. Assume that saliva does not change the iodine solution.

(a) The starch was changed to sugar by the action of saliva . . . . (U) a.
(b) Saliva digested the starch . . . . (U) b.
(c) Starch acted upon the iodine . . . . (R) c.
(d) Saliva produced a change in the starch . . . . (R) d.
(e) Starch mixed with iodine solution did not turn blue . . . (F) e.

Sample No. 4:[2]

R = Reasonable interpretation of the results obtained.
U = Interpretation might be true, but insufficient facts are given to justify it.

[1] *Ibid.*, P. E. A., Test 60.
[2] *Ibid.*, P. E. A., Test 62.

F = Interpretation contradicted by the results obtained.

An approximate distribution of energy in the infra-red, visible, and ultra-violet portions of the radiation of different sources of light, expressed in percentages, is shown in the table below.

PERCENTAGE OF TOTAL ENERGY OF VARIOUS LIGHT SOURCES

	Sunlight	Carbon Arc	Incandescent Lamp	Quartz Mercury Arc
Infra-red (heat)	78	85	90	52
Visible	15	10	9	20
Ultra-violet	7	5	1	28

(a) Most of the energy of sunlight is available as visible light . . . . ( ) a.

(b) The carbon arc releases a larger portion of energy as ultra-violet light than does any of the other sources. . . . ( ) b.

(c) Less than 10% of the energy furnished by an incandescent electric lamp is used in giving off visible light. . ( ) c.

(d) The quartz mercury arc furnishes a larger proportion of energy as ultra-violet light than does the sun. . . . ( ) d.

(e) Most of the energy of all the sources of light listed is given off as heat or "infra-red" rays. . . . . ( ) e.

(f) The quartz mercury arc is more effective for health treatments than sunlight. . . . . ( ) f.

(g) On a cloudy day the proportion of total energy in the form of ultra-violet light from sunlight is less than 7%. ( ) g.

Sample No. 5:[1]

Directions: In each of the following exercises, an experiment is described. Below the description of the experiment are several statements which have been suggested as interpretations of the experiment. Assume that the facts given in the description of the experiment and in the results obtained are correct, then on the basis of *these facts only* consider each statement.

Mark with a 1—every statement which is a reasonable interpretation of the results obtained.

2—every statement which might possibly be true but for which insufficient facts are given to justify the interpretation.

[1] Taken from Coöperative Chemistry Test, Part II, Ohio State University, Columbus, Ohio.

3—every statement which cannot be true because it is contradicted by the results obtained in the experiment.

1. Hydrogen gas under a pressure of 25 atmospheres was bubbled through water at a temperature of 25° C. The number of cc. of hydrogen, at standard conditions of temperature and pressure dissolved per gram of water at 25° C. was found. This was done ten different times and the average number of cc. of hydrogen at standard conditions per gram of water at 25° C. was calculated.

The same procedure was followed in finding the average number of cc. of hydrogen at standard conditions dissolved per gram of water at 25° C. but under different pressures. The results are given in the following table:

Atmospheres of Pressure	Average Number of cc. of Hydrogen per Gram of Water
25	.44
50	.87
100	1.73
200	3.39
400	6.57
800	12.46
1,000	15.20

(a) As the pressure was increased the amount of hydrogen dissolved in the water was decreased................( ) a.
(b) Raising the temperature of the water decreases the amount of hydrogen the water will dissolve..........( ) b.
(c) Hydrogen will not dissolve in water at the pressures used in this experiment...........................( ) c.
(d) At 2000 atmospheres of pressure the amount of hydrogen dissolved is greater than at 1000 atmospheres....( ) d.
(e) As the pressure was increased from 25 to 1000 atmospheres the amount of dissolved hydrogen was increased...( ) e.
(f) Each time the pressure was doubled the amount of hydrogen dissolved in the water was more than doubled...( ) f.
(g) Stirring the water decreases the amount of hydrogen which will dissolve in the water....................( ) g.
(h) More hydrogen will dissolve in the water in 2 hours than in 1 hour...................................( ) h.

It should be pointed out at this point that the test on "Interpretation of Data" made up of problems of the three-

response type are not as valid as tests made of problems of the five-response type cited earlier. It has been found, however, that these three-response tests are particularly useful at the levels below the senior high school. In fact, they have been used down as far as the fifth grade for measuring the ability to interpret data.

The Science Committee of the Wisconsin Education Association [1] has developed a series of tests on "Cause and Effect Relationships" which give evidence on the ability of students to distinguish between cause and effect and to establish causes for observed effects. Below are given the directions and several sample items selected from these tests.

Directions: This is a test of your ability to distinguish the cause-and-effect relationships between paired occurrences. Each item of the test consists of two such paired occurrences which have occurred or do occur approximately together. So far as time is concerned, one might be the cause of the other. Each pair can be classified under the headings A, B, C, D, or E, which are given below and at the top of each page of the test. You are to classify the items by checking in the corresponding column as shown in the example.

	A	B	C	D	E
A. The first is practically the sole cause of the second	x				
B. The first is one of a number of important contributing causes of the second		x			
C. The first contributes only slightly to causing the second			x		
D. Both are results of the same general cause or causes				x	
E. The first bears no causal relationship to the second					x

[1] Science Committee of the Wisconsin Education Association, *op. cit.*, "Cause and Effect Relationships Test in Science," Form A.

Example:

	A	B	C	D	E
The branches of a tree wave to and fro; a nearby windmill turns..................				x	

Sample Items:

(a) A woman found a four-leaf clover; that night she held good cards at bridge.
(b) An electric circuit was closed; lights on the circuit lighted.
(c) The sun shines on leaves of a plant; carbohydrates are manufactured in the leaves.
(d) The weather suddenly becomes colder; moisture collected on the inside of the windows.
(e) A tire blew out; the car went into the ditch.
(f) A telephone wire was being used for conversation; the wire hummed.
(g) A man working in the sun did not perspire; he was overcome by the heat.

The Science Committee [1] of the Wisconsin Education Association in an attempt to determine the characteristics exhibited by a person having a scientific attitude of mind, found that the ability to distinguish between fact and theory was rated high as one of the elements by science teachers consulted in the study. On the basis of the evidence of this study the above committee developed a test designed to evaluate the ability of high school students to distinguish between fact and theory. This test has been through several editions and has been given to several hundred students in the high schools of Wisconsin. There are one hundred items in the test. Below are given the directions for the test, an example, and several items selected at random.

Directions: This is a test of your ability to distinguish between fact and theory. The items of the test are statements which can be classified under the headings A, B, C, or D. Shown below and at the top of pages 2 and 4 of the test, you are to classify each individual item by checking in the corresponding column as shown in the example.

[1] *Ibid.*, "Fact-Theory Test in Science," Form A.

	A	B	C	D	E
A. Statements of well-established facts.......	x				
B. Statements of well-established theories generally accepted by authorities...........		x			
C. Statements of theories which are questioned by some authorities....................			x		
D. Statements of popular beliefs held by some people but not supported by evidence.....				x	
E. Statements about which you do not know enough to classify......................					x

Example:

	A	B	C	D	E
The earth receives light from the sun......	x				

Sample Items:

(a) The pressure of water varies with the depth.
(b) Fish is better brain food than bacon or other meat.
(c) Two molecules of hydrogen unite with one molecule of oxygen to form two molecules of water vapor.
(d) In a bar magnet, each molecule is a magnet.
(e) The moon has no atmosphere.
(f) Lake Michigan was formed by glacial erosion.
(g) All life comes from previously existing life.
(h) Flat, blunt fingers indicate a tendency to steal.

It should be pointed out that considerable difficulty may be experienced in designing an acceptable scoring key for such a test as the one sampled above. At best such a key can only represent the opinion of the group making up the key.

It is basically essential that young people living in a chaos of propaganda, quacks, spurious advertising and the like, gain facility in the skills and abilities that will enable them to successfully combat such influences as they attempt to solve their problems.

Magazines, the radio, and the movies are agencies which constantly confront young people with problems of the above type. The school must assume responsibility for training the youth of today to think logically, to recognize and evaluate assumptions, and to distinguish fact from theory. It is desirable therefore to attempt to evaluate growth in these abilities.

The Evaluation Staff of the Commission on the Relation of School and College [1] have worked out certain techniques for securing evidence on the ability of students to distinguish between facts and assumptions, to recognize those most important assumptions basic to a conclusion, to develop a logical proof, and support conclusions with sound arguments. A sample problem taken from one of these tests [2] will illustrate the use of the techniques developed.

ARE YOU LEARNING TO RECOGNIZE AND EVALUATE ASSUMPTIONS?

A small piece of magnesium will ignite and burn with a bright light in an atmosphere of chlorine gas, leaving white ashes. Bill secured some chemicals, which when mixed together and heated, gave off a colored gas. He collected some of this gas in a bottle. The chemistry teacher gave him a small piece of magnesium. Bill put it in the bottle of colored gas. The magnesium ignited, burned with a bright light, and left white ashes. Bill told his friends that his results conclusively proved that the colored gas was chlorine.

Part 1. Directions: All of the statements below are related in some way to the problem which has been stated. Suppose for the moment that you personally had been present in the problem. Under those circumstances you would probably accept some of the statements of matters of fact, others of them you would regard as assumptions. By assumption we mean a statement that is open to doubt; one that may or may not be true and which in this particular situation would not be acceptable as a fact. Of the statements below, which do you regard as assumptions and which as matters of fact? Place a check mark in the appropriate column before the statement.

Part 2. Directions: Read over again only those statements marked as *Assumptions*. Place a check mark after those *TWO Assumptions* which are absolutely necessary in proving that the gas was chlorine. Do not mark more than two.

[1] *Op. cit.*

[2] *Op. cit.*, "Nature of Proof," P. E. A., Test 5.2A.

Fact	Assumption	LIST OF STATEMENTS	
		(a) Chlorine is not the only gas in which magnesium will ignite, burn with a bright light, and leave white ashes. ——	a.
		(b) The material the chemistry teacher gave him was magnesium. ——	b.
		(c) Chlorine gas is the only gas in which magnesium will ignite. ——	c.
		(d) Chlorine gas is the only gas in which magnesium will ignite, burn with a bright light, leaving white ashes. ——	d.
		(e) Bill mixed and heated some chemicals which gave off a colored gas. ——	e.
		(f) A small piece of magnesium will ignite and burn with a bright light in an atmosphere of chlorine gas, leaving white ashes. ——	f.
		(g) The colored gas must be chlorine. ——	g.
		(h) Chlorine gas is the only gas in which magnesium will burn with a bright light. ——	h.
		(i) Bill collected some of the colored gas in a bottle. ——	i.
		(j) The properties of the colored gas in the bottle were the only cause of the magnesium igniting, burning with a bright light, and leaving white ashes. ——	j.
		(k) Bill put a small piece of magnesium in the bottle. ——	k.
		(l) The properties of the colored gas in the bottle were not the cause of the magnesium igniting, burning with a bright light, and leaving white ashes. ——	l.
		(m) The magnesium ignited, burned with a bright light, and left white ashes. ——	m.

ARE YOU LEARNING HOW TO DEVELOP A LOGICAL PROOF?

When arguments for or against some proposition are presented in newspapers, magazines, speeches, or textbooks, we often feel that the discussion could have been made more logical. Authors sometimes put in statements that are really unnecessary to prove their point; at other times they leave out important arguments; on still other occasions they arrange their statements in such poor order that the conclusion does not seem to be based on or to grow out of the arguments.

Part 3. Directions: Suppose *you* were describing this experiment in order to prove that chlorine gas was collected. What are *all* of the *absolutely necessary* steps in the complete development of the proof? Use as many of the above statements as are *necessary* and place the letters of these statements in their proper order on the line below. Do not use any unnecessary statements.

ARE YOU LEARNING TO SUPPORT YOUR OWN CONCLUSIONS WITH SOUND ARGUMENTS?

Part 4. Directions: In Part 3 of this test you presented a logically developed proof which reached the conclusion that the colored gas Bill made must be chlorine. You may or may not believe that it has been adequately proved that the colored gas must be chlorine. Check the following statement which best represents your own personal opinion as to the nature of the gas.

____a. I believe that the colored gas Bill made was chlorine.

____b. I do not believe that the colored gas Bill made was chlorine.

____c. I do not believe that it has been adequately proved that the colored gas Bill made was chlorine.

Write out the reasons you have to support your opinion.

A bulletin prepared by a group of science teachers working at the 1937 Summer Workshop of the Progressive Education Association [1] contains many tests constructed to evaluate student ability to recognize and evaluate assumptions. Any person interested in this aspect of evaluation in science will

[1] Progressive Education Association Summer Workshop. Materials Prepared by Participants in the Science Group. Progressive Education Association, *Evaluation in the Eight-Year Study*, University of Chicago, 6010 Dorchester Avenue, Chicago.

find many helpful suggestions as to technique and type situations by consulting this excellent monograph.

Frequent classroom testing with situations of this sort should enable the teacher to readily discern those students who need help in distinguishing between fact and assumption. Also the class discussion of the results of such a test after it has been scored should offer excellent teaching opportunities, as questions are raised as to why this or that answer was or was not correct.

SETTING AND TESTING HYPOTHESES. In Chapter III the several specific abilities involved in this aspect of problem-solving behavior were mentioned. There probably has been less work done on the evaluation of these abilities than on any other aspect of problem solving, and yet it is one of the most important places where evidence is needed. This is true because setting and testing hypotheses has had little attention in so far as instruction in science is concerned, and therefore teachers need tests for finding out the extent to which the abilities are present or absent before very much can be done in developing them.

It is possible to secure a very rough idea of the ability of students to test hypotheses by making up a test such as the following:

Directions: Below and on the following pages are some statements which some people think are true and some people think are false. Describe the procedure which should be followed in finding out whether or not the statement given is true.

Always describe the best way that you can think of for testing the truth of the statement given. Write your answer in the blank space below the statement. If you need more space for any answer, use the other side of the page.

The following sample shows you what you are to do.

Sample: A light iron ball falls as rapidly as a heavy iron ball.

To find out whether this statement is true or false one might drop two iron balls of different weights from a high place. The time for each to fall to the ground could be measured and written down. The balls should be the same shape and size. With such iron balls, the resistance of the air would probably be about the same on each ball.

If this were not the case, the experiment should be tried in a vacuum on a smaller scale. If after a number of trials, it was found that they reached the ground at about the same time, one could feel sure that the statement made above was true.

Now you describe in detail how you would set out to discover whether the situations listed in the following were true or false.

List of Statements:

(1) Most of the material of which trees are composed comes from the soil.
(2) Tiny plants called "moulds" cause the rotting of fruits.
(3) Drinking water with one's meals retards digestion.
(4) When animals grow heavy fur in the late fall, the winter will be more severe than usual.
(5) The volume of a given mass of gas varies with its temperature.
(6) When taking a picture of an object with a camera, the farther the object is from the lens, the smaller will be its image on the camera film.
(7) The red color of most rocks and soil is due to the presence of the element iron in these rocks or soil.
(8) The daily range in temperature is greater at inland places than at places on the shores of large bodies of water.
(9) Trout do not occur in many streams because the temperature of the water is too high.
(10) A certain species of fungus which is found in many dead or dying elm trees causes the death of these trees.
(11) Reforestation reduces the danger of floods.
(12) Chemical actions are speeded up by applying heat.
(13) One can tell whether or not a substance is starch by treating it with iodine solution. If the substance turns blue it is starch.
(14) Destruction of the small green plants called "algae" in lakes and streams reduces the fish population.
(15) Dogs would die if kept in an atmosphere of pure oxygen for an hour.
(16) Rats instinctively refuse to eat poison.
(17) Weeds reduce the yields of crops because the weeds take away from the soil the mineral matter required by the crops.
(18) Green plants use the nitrogen of the air as a source of nitrogen for their growth.
(19) Plants lose water into the air through their leaves.
(20) Starch forms in the leaves of plants only in the sunlight.

The above list of hypotheses was formulated by a group from the Evaluation Staff of the Commission on the Relation of School and College.[1]

These statements are listed not so much as a specific test within themselves, but as types of statements which may be used in constructing such a test. Obviously items should be selected which are new to pupils and in which they have had no instruction.

Frutchey and Tyler [2] have described methods for planning experiments and testing hypotheses. The following sample items will illustrate the methods proposed.

Sample Item:

How can one find out that a certain muscle in a frog's hind leg is an extensor and not a flexor?

It would need to be shown that:

(a) The muscle relaxed.............................( ) a.
(b) The leg did not bend when the muscle contracted...( ) b.
(c) The leg moved when the muscle contracted........( ) c.
(d) Other muscles which were not stimulated did not extend the leg....................................( ) d.
(e) The leg extended when the muscle contracted........( ) e.
(f) The muscle is a striated muscle....................( ) f.

Procedures which would need to be used:

(g) Tie the ends of a muscle dissected from the hind leg of a freshly killed frog to the ends of a hinge............( ) g.
(h) Suspend the hind leg of a freshly killed frog so that the leg is free to move in both directions..............( ) h.
(i) Stimulate the muscle with an electric current.......( ) i.
(j) Examine the dissected muscle under a microscope....( ) j.

Drawing Conclusions and Making Generalizations. The evaluation of this aspect of problem-solving behavior has had more attention from teachers than any other single one. Since the time when laboratory reports were first introduced, science teachers have been evaluating the ability of students to draw conclusions from specific evidence. It is probably true, however, that the routine grading of experiments from

[1] Evaluation Staff, *op. cit.*
[2] Frutchey, F. P., and Tyler, Ralph W., *op. cit.*, p. 247.

the various sciences has not revealed the extent to which students made progress in the ability.

In this section an attempt will be made to show how the evaluation of the abilities involved in drawing conclusions and making generalizations may be made somewhat more objective than it can be in the grading of experiments.

One method of building tests for this ability is reported by Tyler.[1] Working coöperatively with certain subject-matter departments at the Ohio State University, he devised tests for this ability as well as other aspects of scientific thinking.

Situations were first collected which required the student to draw reasonable generalizations from specific experimental data. Many of these situations were taken from current research in various fields. One sample will show the type of situation used.

Sample Situation:

A coleus plant exposed to full sunlight became green. A similar coleus plant exposed to only red rays of light became green. A similar coleus plant exposed to only orange and yellow rays of light became green. A similar coleus plant exposed to only green rays of light became green. A similar coleus plant exposed to only blue-violet rays of light became green.

Students were asked to read the statement and then write down the most reasonable generalization which could be made from the data. The scoring of these tests was found to be rather laborious but quite objective. Further experiment and refinement has developed several short-cut techniques more easily scored and which correlate very well with the results on essay responses used at first.

One such form has been used by Koopman [2] as a part of a general test on Steps in Problem Solving. A sample situation taken from this test will show the technique used.

Sample:

Situation B: Assume the following statements are true. A young man vacationing at a bathing beach, rented a canoe for a day.

[1] Tyler, Ralph W., *Constructing Achievement Tests*, Ohio State University, Bureau of Educational Research, Columbus, Ohio.

[2] Koopman, G. Robert, Associate Director, Division of Curriculum Research, Michigan Department of Public Instruction, Lansing, Michigan.

When he had paddled 500 yards off shore, the canoe upset and the young man was drowned. He held insurance covering drowning at bathing beaches. The insurance company refused to pay, claiming that he did not drown at a bathing beach.

Check the conclusion you think can best be drawn from the above event:

____1. The insurance company should pay the claim.

____2. We cannot decide whether the insurance company should pay the claim unless we have more information.

____3. The insurance company should not pay the claim.

Check any of the following statements you feel support your conclusions:

____a. The insurance company should pay the claim since the young man was insured against drowning at a bathing beach.

____b. The insurance company should not pay the claim since 500 yards off shore is too far to be called "at a bathing beach."

____c. The converse of a given proposition is not necessarily true.

____d. We need a clear-cut definition of "at bathing beaches."

____e. A changed definition will produce a changed conclusion although the argument from each is logical.

____f. The insurance company should not pay as the young man drowned as a result of the canoe upset.

____g. We need to know how much the claim was.

____h. If we accept the assumptions, this conclusion must follow.

Also in this area the Evaluation Staff of the Commission on the Relation of School and College have developed a test to determine whether students can apply certain principles of logical reasoning. The principles used in the test are the if-then, the use of ridicule, the indirect argument, and the need for careful definition.

APPLYING PRINCIPLES IN NEW SITUATIONS. Learning, for the most part, becomes effective only in so far as the learner is able to make use of it in adjusting to new situations. In most areas learning should result in the mastery of certain fundamental principles. The learning cycle may not be regarded as complete until the student is able to use the prin-

ciples in new contexts. The study of the opinions of many teachers as well as of the responses of students to essay questions reveals that principles are commonly used either to explain some phenomenon or to predict what will happen under a given set of circumstances.

The application of principles as a goal for science instruction is not new. For many years there have been materials in the literature of the field related to the attainment of this objective. It is important that teachers have some way of evaluating the progress of students toward this objective, and therefore a part of this chapter will be devoted to a consideration of ways for measuring objectively the abilities involved.

Every science teacher interested in this aspect of evaluation should secure the following materials prepared under the direction of the Evaluation Staff of the Eight-Year Experiment of the Progressive Education Association:[1]

1. Raths, Louis E., *Application of Principles*, Bulletin 5.
2. Frutchey, Fred P., *Application of Principles*, P. E. A. Bulletin 859.
3. Zechiel, A. N., *Testing Application of Principles*, P. E. A. Bulletin 874.

The essay type question for testing the ability to apply principles has long been in use. An example of such questions is:

> Explain why a warm, dry, windy day is good for drying clothes; or tell what will happen if acid foods are cooked in aluminum pans.

In such questions the teacher is attempting to test the ability by making use of it in explaining or predicting. In scoring answers to such essay questions, it is very difficult to be objective and also to secure evidence of the progress of students in developing the ability. It is further very hard to isolate the specific causes of difficulty so that effective remedial instruction may be applied. Further, the essay method of evaluation is cumbersome, time consuming, and limits the number of principles which may be tested in a given time.

[1] Evaluation Staff, *op. cit.*

To obviate these, and other limitations of the essay examination for evaluating this ability, the Evaluation Staff of the Eight-Year Study[1] have developed an objective technique which correlates very highly (.9) with results obtained on essay questions. Two sample situations developed after this technique will illustrate the method.

Sample Situation: [2]

A motorist on a vacation in the West had his tires checked to 35 pounds at a gas station on the edge of Death Valley Desert. That evening he drove up into the mountains where he encountered snow on the road, and stopped for the night at an inn. What happened to the tires that night?

Directions: Choose the conclusion which you believe is most consistent with the facts given above and most reasonable in the light of whatever knowledge you may have, and mark the appropriate space on the Answer Sheet.

Conclusions:

A. The tires on the car were flatter.
B. One of the tires, an old, thin one, blew out.
C. No change was observed in his tires.

Directions: Choose the reasons you would use to explain or support your conclusion and fill in the appropriate spaces on your Answer Sheet. Be sure that your marks are in one column only—the same column in which you marked the conclusion. (You may want to refer back to the sample under Problem I.)

Reasons:

(1) As temperature decreases, the pressure exerted and the volume occupied by a confined body of air increase.
(2) It is ridiculous to think that tires do not become flatter on colder days.
(3) Just as a warm piece of metal cools on a cake of ice, so a warm body of confined air decreases in volume when the temperature is lowered.
(4) Tire manufacturers say that tires are flatter in cold weather than in hot weather.
(5) As the motorist drove from the edge of the desert up into the mountains, the temperature became lower.
(6) The air on mountains is much thinner and hence exerts much less pressure.

[1] *Ibid.*
[2] *Ibid.* Taken from Test 1.31, "Application of Principles in Chemistry."

(7) Tires on automobiles are flatter on cold days than on hot days.
(8) When temperature decreases, the pressure of a confined body of air decreases.
(9) The pressure exerted and the volume occupied by a confined body of air remain constant as the temperature of the air changes.
(10) As the pressure of air in an expansible container decreases, the volume of the air decreases.
(11) Cold air is heavier than warm air.
(12) A body of air taken from a valley up to a mountain top would tend to adjust itself to the lower pressure of the surrounding air.
(13) If a tire becomes "soft," it is due to a leak in the tube.

Sample Situation:[1]

In digging a tunnel under a river, some men were working in a sealed compartment where the air pressure was several times as great as the air pressure on the outside. One man's shovel struck a stone causing a large spark which fell on another worker's clothing. Which of the following probably happened?

Directions: Choose the conclusion which you believe is most consistent with the facts given above and most reasonable in the light of whatever knowledge you may have, and mark the appropriate space on the Answer Sheet under Problem VII. (Disregard the spaces for Conclusions D and E in this problem.)

Conclusions:

A. The man's clothing burst into flames.
B. The spark went out in a few seconds.
C. A small hole was burned in the man's clothing before another worker had time to extinguish the flame with water.

Directions: Choose the reasons you would use to explain or support your conclusion and fill in the appropriate spaces on your Answer Sheet. Be sure that your marks are in one column only—the same column in which you marked the conclusion. (You may want to refer back to the sample under Problem I.)

Reasons:

(1) Remembering that temperature of gas is increased when it is compressed, one might conclude that a fire would burn more rapidly where the air pressure was high.
(2) An increase in air pressure lowers the rate of combustion.
(3) Rate of combustion increases as the amount of oxygen present increases.

[1] *Ibid.*

(4) A tunnel worker's clothing will burst into flames when a spark comes in contact with the clothing.

(5) No one but a thoughtless person would fail to appreciate the danger of fire in a sealed compartment.

(6) Air under pressure furnishes a better draft for combustion.

(7) The amount of oxygen in a given space is measured in terms of the number of molecules of oxygen in that space.

(8) Combustion under pressure proceeds at a much more rapid rate so that complete oxidation may be accomplished in less time.

(9) Tunnel workers report that fires burn with amazing rapidity in compressed air compartments.

(10) A fire may be extinguished by removing the combustible material.

(11) When the air pressure in an enclosed space is increased by pumping in more air, the number of molecules of nitrogen, oxygen, and inert gases in that space is increased.

(12) An increase in air pressure has no effect on the rate of combustion.

STANDARDIZED SCIENCE TESTS

1. General Science
    1. Ruch, Giles M., and Popenoe, Herbert F., *Ruch-Popenoe General Science Tests*, World Book Co., Yonkers, N. Y., 1923. Two forms, A and B.
    2. Dvorak, August, *General Science Scales*, Public School Publishing Co., Bloomington, Ill., 1924. Forms R 1, S 2, T 2.
    3. Powers, S. R., *Powers General Science Test*, Bureau of Publications, Teachers College, Columbia University, New York, 1927. Two forms, A and B.
    4. Glenn, Earl R., and Gruenberg, Benj. C., *Glenn-Gruenberg Instructional Tests in General Science*, World Book Co., Yonkers, N. Y., 1932. One form, 35 tests in booklet.
    5. Underhill, O. E., and Powers, S. R., *Cooperative General Science Tests*, Cooperative Test Service, Five forms, 1933 to present.
    6. Boyer, P. A., and Gordon, A., *Boyer and Gordon General Science Unit Tests*, Lyons and Carnahan, Chicago, Ill., 1935.
    7. Hunter, George W., and Knapp, A., *Hunter and Knapp, Mastery Tests in General Science*, American Book Co., 1934.
2. Biology
    1. Blaisdell, J. G., *Blaisdell Instructional Tests in Biology*, World Book Co., Yonkers, N. Y., 1929. One form, 25 tests in one booklet.

2. Oakes, Mervin E., and Powers, S. R., *Oakes and Powers, Test of General Biology*, Bureau of Publications, Teachers College, Columbia University, New York, 1929. Two forms, A and B.
3. Presson, John M., *Presson Biology Test*, World Book Co., Yonkers, N. Y., 1930. Two forms, A and B.
4. Fitzpatrick, F. L., and Powers, S. R., *Cooperative Biology Test*, Cooperative Test Service. Five forms, 1933 to present.
5. Ruch, Giles M., and Cossman, L. H., *Ruch-Cossman Biology Test*, World Book Co., Yonkers, N. Y., 1924.
6. Stemen, J. R., and Myers, W. S., *Biology Tests*, Harlow Publishing Co., Oklahoma City, Okla., 1930. Test 1, 2, 3, 4, 5, 6.

3. CHEMISTRY
1. Powers, S. R., *Powers General Chemistry Test*, World Book Co., Yonkers, N. Y., 1924. Two forms, A and B.
2. Stoddard, G. D., and Cornog, J., *Iowa Placement Examinations, Chemistry Training*, Bureau of Educational Research and Service, University of Iowa, Iowa City, Iowa, 1925. Two forms, A and B.
3. Stoddard, G. D., and Cornog, J., *Iowa Placement Examinations, Chemistry Aptitude*, Bureau of Educational Research and Service, University of Iowa, Iowa City, Iowa, 1925. Two forms, A and B.
4. Glenn, E. R., and Welton, Louis E., *Instructional Tests in Chemistry*, World Book Co., Yonkers, N. Y., 1929. One form, 36 tests in booklet.
5. Jette, E. R., Powers, S. R., and Wood, Ben D., *Columbia Research Bureau Chemistry Tests*, World Book Co., Yonkers, N. Y., 1929. Two forms.
6. Bradbury, G. M., and McGill, M. V., *The 20th Century Practice Exercises and Objective Tests in Chemistry*, Follett Publishing Co., 1931. One form.
7. Dull, C. E., *Tests in Chemistry*, Henry Holt and Co., 1931. One form.
8. Fowler, G. W., and Kane, E. P., *Mastery Tests in Chemistry*, Ginn and Co., 1932. One form.
9. Malin, J. E., *Diagnostic Test in the Mechanics of High School Chemistry*, Public School Publishing Co., Bloomington, Ill., 1932. Two forms, A and B.
10. Noll, V. H., and Powers, S. R., *Cooperative Chemistry Test*, Cooperative Test Service. Five forms, 1933 to present.
11. *Objective Tests in High School Chemistry*, Watson, Harlow Publishing Co., Oklahoma City, Okla.

4. PHYSICS
1. Black, N. Henry, and Burlingame, Frances M., *Harvard List: Elementary Physics Test*, Ginn and Co., 1927. Two forms, A and B.
2. Farwell, H. W., and Wood, Ben D., *Columbia Research Bureau Physics Test*, World Book Co., Yonkers, N. Y., 1926. Two forms, A and B.

3. Stoddard, G. D., and Lapp, C. J., *Iowa Placement Examinations in Physics-Training*, Bureau of Educational Research and Service, University of Iowa, Iowa City, Iowa, 1925. Two forms, A and B.
4. Stoddard, G. D., and Lapp, C. J., *Iowa Placement Examinations in Physics-Aptitude*, Bureau of Educational Research and Service, University of Iowa, Iowa City, Iowa, 1925. Two forms, A and B.
5. Kilzer, L. R., and Kirby, T. J., *Inventory Test for the Mathematics of High School Physics*, Public School Publishing Co., Bloomington, Ill., 1929. One form.
6. Longren, P. V., and Marburger, W. G., *Michigan Instructional Tests in Physics*, Public School Publishing Co., Bloomington, Ill., 1929. One form, 22 instructional tests in booklet and also an initial test.
7. Hurd, A. W., *Final Test in High School Physics*, Bureau of Publications, Teachers College, Columbia University, New York, 1930. Three forms, A, B, C.
8. Glenn, E. R., and Obourn, E. S., *Glenn-Obourn Instructional Tests in High School Physics*, World Book Co., Yonkers, N. Y., 1931. One form, 25 tests in booklet.
9. Kirkpatrick, J. E., and Greene, H. A., *Objective Test Exercises in High School Physics*, Public School Publishing Co., Bloomington, Ill., 1931. One form.
10. Farwell, H. W., *Cooperative Physics Test*, Cooperative Test Service. Five forms, 1932 to present.
11. Stewart, A. W., and Ashbaugh, E. J., *Stewart-Ashbaugh Physics Test*, Public School Publishing Co., Bloomington, Ill. Two forms.
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6. Tests Produced by the Evaluation Staff of the Commission on the Relation of School and College, Progressive Education Association

Sample copies of these are available at the prices listed. They are not available in quantities to schools in general. They are illustrative of unique testing techniques.

Evaluation in the Eight-Year Study Progressive Education Association, 6010 Dorchester Avenue, Chicago

No.	Name of Test	Price
1.3a	Application of Principles (General Science) [2]	$.05
	Explanation of Summary and Tabulation Sheets	.03
	Summary Sheet—Aspects of Thinking	.01
1.31	Application of Principles (Chemistry) [2]	.10
1.32	Application of Principles (Physics) [2]	.10
1.33	Application of Principles (Biology) [2]	.10
1.41	Application of Principles (Social Studies) [1]	.05
	Explanation of Summary and Tabulation Sheets	.03
2.51	Interpretation of Data (Science and Social Studies) [1]	.05
	Explanation of Summary and Tabulation Sheets	.02
3.2a	Literature Questionnaire: The Novel (3 Forms) [1]	.05
	Directions to the Student	.01
3.3	Questionnaire on Voluntary Reading [1]	.03
	Summary Sheet	.03
3.4	Literary Information Test: English Literature [3]	.05
3.5	Literary Information Test: American Literature	.03
3.6	Questionnaire on Reading Interests and Outcomes	.03
3.7	Critical Mindedness in the Reading of Fiction [1]	.03
	Summary Sheet	.02
3.8	Judging the Effectiveness of Written Composition [1]	.03
4.21 & 4.31	Scale of Beliefs Relating to Democracy, Economic Individualism, Labor and Unemployment, Race, Nationalism, Militarism [1]	.05
	Directions to the Pupil	.02

[1] Separate answer sheet, ... 1¢.
[2] Separate answer sheet, ... 1½¢.
[3] Separate answer sheet, ... 2½¢.

No.	Name of Test	Price
	Explanation of Summary and Tabulation Sheets	.02
4.9 & 4.10	Scale of Beliefs Relating to Race, Politics, Business, Family and Religion [1]	.05
	Directions to the Pupil	.02
	Use of the Tests	.01
4.11 & 4.12	Scale of Beliefs (adaption of 4.21–4.31 to junior high school level)	.05
5.11	Application of Certain Principles of Logical Reasoning [2]	.05
	Explanation of Summary Sheet and Tabulation Sheet	.02
5.21	Nature of Proof [1]	.05
7.1	Familiarity with Sources of Information [1]	.05
8.2a	Interest Index [1]	.03
	Checklist of One Hundred Magazines	.05
	Alphabetical List of 1,000 Fiction Authors	.10
	Bulletin 6—Social Sensitivity	.25

[1] Separate answer sheet, ... 1¢.
[2] Separate answer sheet, ... 1½¢.

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Chapter VIII

Science Clubs

DURING the past decade we have witnessed a rapidly growing interest and desire on the part of school administrators and supervisors to utilize extracurricular activities as a means of stimulating pupil participation and initiative in learning. The advantages of clubs over usual classroom procedures have been clearly stated by McKown [1] as follows:

"The Club offers the pupil an opportunity for specialization which he does not have in the classroom. In the classroom his work is formal, in the club it is informal; in the classroom he is told what to do, in the club he chooses; in the classroom his method of dealing with a topic is clearly outlined by teacher imposed restrictions, in the club program the method is of his own devising; in classroom he tries to please the teacher, in the club he works for his own and his club's interests and for the joy of doing this work; in the classroom he conforms to a system, in the club he suits his own convenience. In short, the club represents freedom and expression where the classroom represents conformity and repression."

TYPES AND INTERESTS OF SCIENCE CLUBS.

In a general way science clubs may be divided into two groups: (1) the *specialized interest club*, such as the Radio Club, Camera Club, Aviation Club, Agriculture Club, Nature Club, etc.; (2) the *general type club* such as the General Science Club, Biology Club, Chemistry Club, and Physics Club. Experience has shown that the specialized interest club is very frequently a short-lived club. This is particularly true in smaller schools. Webb [2] has reported on interests of science clubs from data

[1] McKown H. C., *School Clubs*, Macmillan Co., 1929.
[2] Webb, H. A., "Some First-Hand Information concerning Science Clubs," *School Science and Mathematics*, 29: 273–76, 1929.

gathered from nearly two hundred science clubs scattered over the United States.

These data are shown in Table 1. The middle column shows the interests of all the clubs, the right-hand column the interests of small clubs, and the left-hand column the interests of large clubs.

TABLE 1

TYPES OF SCIENCE CLUBS

Large Clubs	No.	All Clubs	No.	Small Clubs	No.
Chemistry	17	General science	44	General science	30
General science	14	Chemistry	43	Chemistry	26
Physics	11	Physics	34	Physics	23
Biology	9	Biology	27	Biology	18
Radio	5	Radio	11	Nature	6
Nature	4	Nature	10	Radio	6
Experiments	2	Miscellaneous	—	Astronomy	4
Geography	2			Photography	4
Photography	2			Experiments	3
Agriculture	1			Aviation	3
Botany	1			Birds	2
Collections	1			Botany	2
Health	1			Current science	2
				Meteorology	2
				Engineering	1
				Field trips	1
				Geology	1
				Physiology	1
				Zoology	1

This investigation further revealed that the size of the clubs ranged from seven members to two hundred forty members; the average being twenty-nine members. Meetings ranged from once a week to once a month with about half the clubs holding their meeting each alternate week. The clubs were about evenly divided as to the time meetings were held; fifty per cent holding their meetings during school hours and fifty per cent holding their meetings after school hours.

ORGANIZATION OF A CLUB.

The best results seem to be obtained in club work when the group is formally organized. This requires the adoption of a

constitution. Meister, an expert in science club work, suggests the following questions to be answered during the framing of the constitution:

(1) What shall be the aim and purpose of our Science Club?
(2) What shall be its name?
(3) Membership:
  (a) Who can become a member?
  (b) What must a boy or girl do to become a member?
(4) Meetings:
  (a) When shall they be held?
  (b) Where?
  (c) How often?
  (d) Who shall call for special meetings?
(5) Money:
  (a) Shall we pay dues?
  (b) How much?
  (c) Can we levy taxes?
  (d) How? How much?
  (e) For what shall the money be used?
(6) Expelling members:
  (a) For what reason or reasons?
(7) The business program:
  (a) How long shall it be?
  (b) What shall be the procedure?
(8) The science program:
  (a) How many different activities shall the club have?
  (b) Who shall decide upon and arrange these programs?
(9) Officers:
  (a) When shall elections take place?
  (b) How often?
  (c) What officers shall we have?
  (d) What shall be the duties of each officer?
  (e) How can an officer be impeached?
  (f) How can an officer resign?
  (g) Shall officers filling positions left vacant be appointed or elected? And how?
(10) Any other regulations you think it important to put into the constitution.

Most science clubs find it necessary to have the following officers: President, Vice President, Secretary, Treasurer, Sergeant-at-Arms, and a Librarian. At the first meeting a

set of temporary officers is elected. A committee to formulate a constitution is appointed. At the next meeting the constitution is discussed, revised if necessary, and finally adopted by a majority vote. A permanent set of officers is then elected as specified in the constitution.

TYPES OF PROGRAMS.

The challenge of maintaining interest and enthusiasm in a science club can be met in large part by having interesting and varied programs.

The adviser or sponsor of a club should keep in mind, however, that the club is organized for the pupils.

They should plan and execute the programs. Immature pupils do need guidance, however, and the adviser should see to it that planning for programs is not left to the last minute. The following activities have been found worth while in science club work and are offered as suggestions:

(1) *Visual programs* in which lantern slides, motion pictures, microprojector, or some other concrete visual aids are employed.
(2) *School journeys.* Visits to such places as a power plant, a mill, telephone exchange, weather bureau, zoological and botanical gardens, a greenhouse, city water supply, filtration plant, modern dairy, and museums are always interesting and help to create interest in science.
(3) *Work periods.* Some club meetings should be set aside for the members to engage in individual work such as doing experiments, preparing demonstrations, or making posters and exhibits. In some science clubs every other meeting is made a work period.
(4) *Current events.* Some clubs devote one meeting a month to reports and discussions of new developments in science as reported in recent scientific magazines and newspapers.
(5) *Science spelling match.* This is an old-fashioned spelling bee in which only science words are used.
(6) *Special speaker program.* Science clubs enjoy hearing occasionally some expert or specialist such as a doctor, an engineer, a forester, or a bee-keeper.
(7) *Science almanac.* This program usually consists of reports on famous scientists born in a particular month.

(8) *Science question-box.*
(9) *Science debates.*
(10) *Science plays.*

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Section II

Materials and Devices for Teaching Science

(Visual and Other Sensory Aids)

Chapter IX

Some Aspects of the Psychology of Learning Science by the Use of the Visual Aids

IT has been said that sensory experience is the foundation of intellectual activity. Indeed it seems that all intellectual activity begins with and depends upon sense perceptions.

Human beings derive their experiences mainly from three sources: (1) direct sensory contact; (2) pictures or some other forms of representation of objects, phenomena, and relationships; and (3) oral or printed words or symbols. And of these three possibilities the third is of little value unless proper sensory experience is provided to serve as a basis for interpreting the oral and written words. It is not likely, for example, that the term "chemical action" would have much meaning to a person who has never heard the sizzling in a test tube or who has never seen precipitates form. What meaning would the term "atmospheric pressure" have to an individual who has never seen an exhausted tin can crushed by the weight of the atmosphere or who has never watched the lowering of a barometer in a partial vacuum during the varying stages of exhausting the enclosed air? The words "nucleus" and "vacuole" are vastly more meaningful after a student has studied biology and has seen cells under a microscope.

In science teaching we are greatly concerned with facts and concepts. Facts are statements which result from sensory perception. A biology teacher may exhibit a violet before his class and the pupils may state that the flower is blue. In stating this simple fact the pupils have associated the quality of blueness with the violet.

A concept may be simple or it may be complex. A pupil's concept of a flower might be that it is the reproductive center of the plant, that it has sepals, petals, stamens, and pistils, that it produces sperms and eggs, that the fertilized

egg results in the new baby plant, and that the fruit develops from the flower. This would be a relatively complex concept.

Good science teaching requires (1) that the concepts to be developed in a science course be carefully defined by the teacher, and (2) that learning exercises and experiences be provided which will stimulate the pupils and which will make for permanency of the desired outcomes. If the teacher fails to do these things, much of the teaching is apt to be dry verbalism. Many of the pupils will hear and use scientific words without understanding the true meaning of the words, and furthermore they will associate together words and meanings which do not belong together. The data [1] given in the following table clearly illustrate this point.

TABLE 2

CONCEPTS EXPRESSED IN ANSWER TO THE STATEMENT, "TELL ALL YOU KNOW ABOUT BACTERIA."

CONCEPTS	NO.	PER CENT
1. Bacteria are harmful and useful	48	64.0
2. Bacteria are tiny, invisible organisms	40	53.3
3. Bacteria cause diseases	38	50.6
4. Bacteria are germs (partly naive)	25	33.3
5. Bacteria multiply rapidly	19	25.3
6. Bacteria cause decay	18	24.0
7. Yeast cells are bacteria (naive)	16	21.3
8. Bacteria are nearly everywhere	16	21.3
9. Bacteria cause fermentation	15	20.0
10. Bacteria are animals (naive)	12	16.0
11. Bacteria are one-celled organisms	12	16.0
12. Bacteria thrive in warm places	12	16.0
13. Bacteria cause milk to sour	11	14.6
14. Bacteria are destroyed by intense heat	9	12.0
15. Bacteria are plants	9	12.0
16. Bacteria are tiny organisms	9	12.0
17. Bacteria cause foods to spoil	9	12.0
18. Bacteria are useful in cheese making	9	12.0
19. Molds are bacteria (naive)	8	12.0
20. Bacteria are on flies	7	9.3
21. Bacteria reproduce by dividing	5	6.6
22. Bacteria live in dark places	5	6.6
23. Bacteria need sun and light for growth (naive)	5	6.6
24. Bacteria are killed by sunlight	4	5 3

[1] These data are part of an unpublished research study conducted by Dr. Heiss

Seventy-five college freshmen, shortly after they had entered college, were given a series of free-association tests. In this particular case they were instructed to write all they knew about bacteria. The students were stimulated to express themselves freely and they were given all the time desired.

The table gives the concepts and number and percentage of the seventy-five freshmen who expressed each concept.

Concepts expressed by less than four people are not given on the table. It will be noticed from an examination of the table that some of the concepts expressed are scientific and some of the concepts expressed are naive.

The data as analyzed in Table 2 are perhaps interesting and important but they do not give a complete picture of the situation. To get a true picture of the situation it is necessary to examine the "concept pattern" of each individual. In order that this chapter may be kept within reasonable bounds it is not advisable to do this for all seventy-five students, but we can examine a few samples. Graphic pictures of the "concept pattern" for bacteria held by four students are presented. These are designated as cases A, B, C, and D.

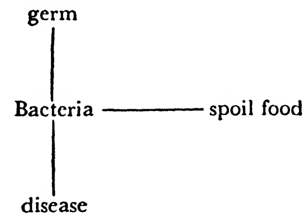
It should be noticed that in each case, except perhaps Case A, the students' conception of bacteria is a combination of scientific and naive notions. This is true for about 55% of this group of freshmen. This is not an exceptional situation. In fact, it was discovered that their concepts of such physical phenomena as light, heat, and electricity tended to be even more naive than scientific.

The writer does not know the cause of these effects but it seems a tenable hypothesis that verbalism constituted the major weakness in the teaching which produced these effects and that many of the pupils learned words without a sense of their real meaning.

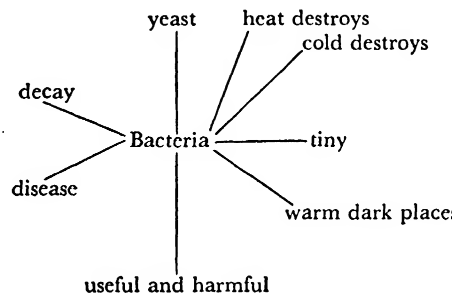
An interesting example of verbalism due to insufficient ex-

at the East Stroudsburg State Teachers College. All of the freshmen had had at least one course in science. Sixty-three of the 75 had had general science and 60 of them had had biology.

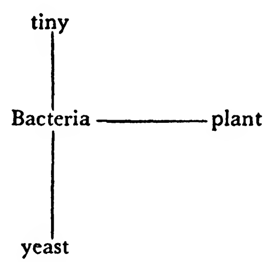
Case A
Science Courses
None



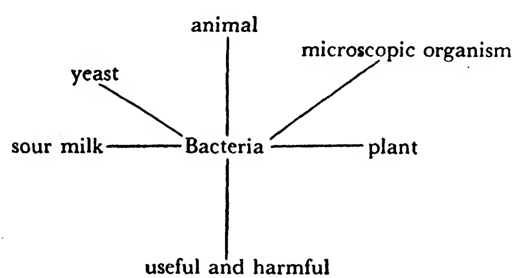
Case B
Science Courses
General Science (1 yr.)
Biology (1 yr.)
Chemistry (1 yr.)
Physics (1 yr.)



Case C
Science Courses
General Science (1 yr.)
Chemistry (1 yr.)



Case D
Science Courses
General Science (1 yr.)
Biology (½ yr.)
Zoology (½ yr.)
Chemistry (1 yr.)
Physics (1 yr.)



perience is found in the story related by Messenger.[1] A little girl from the city went to visit people in the country. One day the little girl saw a cow chewing her cud beneath an evergreen tree. After watching the cow in action for some time she went into the house and said to the woman there, "Your cow is out under the Christmas tree chewing gum."

The program for teaching science as outlined in the *Thirty-First Year Book* [2] of the National Society for the Study of Education emphasizes major generalizations as the important objectives of science teaching. In the *Thirty-first Yearbook* it is proposed "that the curriculum in science for a program of general education be organized about large objectives, that understanding and enlargement of these objectives shall constitute the contribution of science teaching to the ultimate aim of education, and that the course of study be so organized that each succeeding grade level shall present an increasingly enlarged and increasingly mature development of the objectives."

In this connection it is of paramount importance for science teachers to bear in mind that major generalizations are abstractions. To tell pupils, for example, that "space is vast" without first having given them wide, varied, and concrete instruction about the heavenly bodies would be the dullest and poorest kind of science teaching imaginable.

It is important that science teachers clearly understand how generalizations develop. The following quotation [3] is clear and succinct on this point.

"Mental growth is in part the result of two apparently antithetical processes: differentiation and integration. Recent experimental investigation has established the fact that original behavior is highly integrated, that the organism responds to stimuli as a whole. For example, Lewin studied the re-

[1] Messenger, J., Franklin, *An Interpretative History of Education*, The Thomas Y. Crowell Co., New York, 1931, pp. 213–14.

[2] *Thirty-first Yearbook*, National Society for the Study of Education, Part 1, " A Program for Teaching Science," Public School Publishing Co., 1932.

[3] Hoban, Charles F., Hoban, Charles F., Jr., and Zisman, Samuel B., *Visualizing the Curriculum*, The Cordon Co., New York, 1937, pp. 16–17.

sponses of infants to various food substances and found that the very young child's reaction was a total bodily response. If lemon juice was fed an infant, the withdrawal was not merely a withdrawal of the tongue and head, but of the arms, legs, and torso. Similarly, if warm oatmeal was fed the infant, the response was a total bodily response toward the food, *i.e.*, the head, arms, legs, and torso were directed toward the desired food. The infant reacted in unitary, undifferentiated gross bodily movement toward or away from the stimuli.

"Through the course of experience, differentiation of response develops out of total unitary response. This differentiation is not limited to gross bodily movements but is observable throughout the entire range of child behavior. The child will soon differentiate milk from water, the bottle from the breast, the mother from the nurse, the mother from the father, the other children from the parents, etc. Psychological objects are differentiated out of their environment as they attain significance to the child through his needs.

"It is in this elementary process of differentiation that visual aids have their value. Without concrete experience with objects there is no differentiation of this object out of vast environment. It does not exist as such for a child. The little girl who saw a cow standing under a Christmas tree chewing gum had little differentiated experience either with evergreen trees or with chewing movements not involved in actual eating. To the child Christmas trees and evergreen trees were synonymous because her only previous concrete experience with evergreens was in their relation to Christmas ceremonials. Similarly, her only previous experience with chewing response other than eating was chewing gum. Hence, to the little girl the cow was actually chewing gum under a Christmas tree.

"Upon the kindly explanation of the woman, the child's responses probably became differentiated. Evergreen trees came to exist in new relationships beyond their role in Christmas ceremonials through actual concrete experience with these trees. The child's responses to chewing gum were ex-

panded beyond the limits of chewing gum through actual concrete experience in a new and now differentiated situation. Her experience had become richer.

"But differentiation is generally accompanied by a secondary process of integration. As experience with evergreen trees becomes differentiated into richer patterns through experience with firs, pines, spruces, cedars, etc., the abstraction of 'evergreen trees' develops through the emergence of a general pattern of trees having the common quality of a peculiar type of foliage which remains on the trees through the year. Through some common element or elements the various differentiated patterns of responses become integrated into a higher order of reaction. Each concrete experience becomes integrated into a subordinate relationship within higher-order response of 'evergreen trees.' Thus through the process of integration of differentiated concrete experiences that type reaction is developed which is known as abstraction and generalization. *The abstraction or generalization attains a richness of meaning to the extent that concrete experience is wide and varied, and to the further extent that this wide and varied concrete experience becomes integrated into a higher order of relationships.*"

Science teaching should also increase the pupil's vocabulary. Words are symbols which represent actions, things, and ideas. Thinking is carried on by the use of symbols, and it is impossible for us to think clearly about anything to which we cannot assign words. However, words (language) are relatively meaningless unless they grow out of concrete experiences. To be effective, science teaching should be built around concrete experiences which make abstract material meaningful. Powers [1] in extensive studies of the nature and difficulty of the vocabulary found in high-school textbooks has shown that the vocabulary burden of these texts is unnecessarily large. There is a trend toward simplification of the materials of science instruction and a trend toward the

[1] Powers, S. R., "The Vocabularies of High School Science Textbooks" and "A Vocabulary of Scientific Terms for High School Students," *Teachers College Record*, 26:1925, 368–92 and 28:220–45.

enrichment of science teaching through a liberal use of vis aids. Both of these trends should be carefully encouraged administrators and teachers of science.

GENERAL PRINCIPLES.

The use of visual aids is not a new development. Some the earliest records left by prehistoric man are picture recor such as drawings in caves in France made by Crô-Magr man many thousands of years ago. In primitive times boys were taught to hunt and fish and girls were taught cook through observation and participation, with the nec sary language explanation. Such famous pioneers in edu tion as Comenius, Rousseau, and Pestalozzi emphasized t importance of visual aids.

In recent years science and invention have opened greater possibilities in the developments of concrete visual a for teachers. Inventions and discoveries in the fields of phot raphy and photoengraving, microscopes, motion pictures, p jectors, charts, and models, all are contributing toward m ing science instruction more meaningful to the pupils.

What is visual instruction? Is it a new method of teachir Or is it a tool?

Visual education is not a new subject or a new meth of teaching. Visual instruction implies the presentation knowledge to be gained through seeing experience. It is means to an end. Its purpose is to provide for enrichment education and learning through maximum use of the se of sight. Visual instruction involves the use of all types visual aids, such as field trips, objects, specimens, mod exhibits, flat pictures, charts, graphs, stereographs, lant slides, opaque projectors, still films, microscopes, and moti pictures.

Partly from experience with the use of visual aids and par from research the following general principles have been veloped as general guides to the use of visual materials.

a. THE EXPOSURE OF PUPILS TO VISUAL AIDS WILL NOT ITSELF GUARANTEE SUCCESSFUL TEACHING. Visual aids mu

be adapted to the intellectual maturity of the pupils and to the nature and extent of the pupil's previous experiences. Furthermore, most visual aids have certain psychological limitations. Flat pictures, for example, lack depth and are frequently not true in color or in size. The teacher of science should become thoroughly familiar with the advantages and limitations of all the various types of visual aids.

b. Visual Aids Are Not Meant to Be a Substitute for Oral and Written Methods of Gaining Knowledge. Rather they are to be used to supplement and enrich other methods of learning.

c. Visual Instruction in the Classroom Should Not Be Confused with Entertainment. Visual aids are not meant to eliminate work or thought. They should be used to make work more interesting and more meaningful and to stimulate pupils to greater activity and thinking.

d. Visual Aids Vary in Their Effectiveness in Direct Proportion to Their Degree of Reality. A biology teacher, for example, in teaching about butterflies would find an actual specimen of a butterfly more effective than a photograph or a slide because the specimen is reality. If the teacher had no specimen of the butterfly but used a photograph or slide instead, the lesson would be more effective than if no visual aid were used. There is a great need for research to determine the relative effectiveness of various types of visual aids in specified science teaching situations.

The proper use of visual aids in science teaching should do at least three things:

(1) Effect an economy of time in learning.
(2) Enrich and vitalize instruction.
(3) Develop correct initial concepts.

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Chapter X

The School Journey

THE school journey is any school exercise designed to provide complete sensory experience with things and phenomena which cannot be brought into the classroom. It involves the taking of pupils to places where the subject matter of instruction may be studied first-hand.

The term "school journey" as used here includes exercises which among science teachers are frequently spoken of as field trips or excursions. It implies a broader meaning than that sometimes applied to field trips and it is used to cover any instructional work done outside the classroom. The school journey is the most real and most concrete of all visual-aid techniques because it brings the pupils into direct contact with objects and phenomena in their natural setting.

ADVANTAGES OF THE SCHOOL JOURNEY.[1]

A strong recommendation for school-journey practice is the fact that it is a coöperative enterprise. Teacher and children join in the project. The child is the active agent; the teacher the wise counselor and skillful guide. Through the teacher's generalship, initiative can be stimulated, powers of self-dependence can be cultivated, and this type of instructional aid made an effective tool in achieving the objectives for which school work is intended. Among the advantages of the school journey are the following:

(1) It shows natural phenomena in their proper settings.
(2) It tends to blend school life with the outside world, putting pupils in direct touch, under learning situations, with things, persons, movements, relationships, environments, occupations, tendencies, trends, functionings.

[1] The list of advantages, the organization and procedure, and the types of school journey lessons have been adapted from Educational Monograph, *Visual Education and the School Journey*, Department of Public Instruction, Commonwealth of Pennsylvania, 1927.

(3) It stimulates interest in natural as well as man-made things and situations, and enables students to know intimately their environment.
(4) It promotes the consideration and solution of problems arising from individual and group participations in natural social settings.
(5) It affords opportunities to develop keenness and accuracy of observation and to experience the joy of discovery.

FIG. 1. A lesson in the Philadelphia Commercial Museum.

(6) It sets up a "challenge" to solve, and this stimulates constructive, creative thinking.
(7) It helps children to organize their knowledge.
(8) It develops initiative and self-activity, making pupils active agents rather than passive recipients.
(9) It provides helpful practices, and thereby cultivates the habit of spending leisure time profitably.
(10) It serves to arouse ambitions and to determine aims.
(11) It provides for valuable correlation of subjects.
(12) It effects a genuine socialization of school procedure.

PURPOSES. Among the definite purposes for which school journeys or field trips may be conducted are:

(1) To serve as a preview of a lesson and for gathering instructional materials.
(2) To create teaching situations for cultivating observation, keenness, discovery—to encourage children to see and know the things about them.
(3) To serve as a means of arousing specific interests as in birds, trees, animals, the heavens, and industrial processes.
(4) To supplement classroom instruction; to secure definite information for a specific lesson.
(5) To verify previous information, class discussions and conclusions, or individual experiments.

ORGANIZATION AND PROCEDURE.

In planning school journeys, a first essential is to make a survey of the immediate and neighboring surroundings in order to list all available materials. From such a survey teachers may familiarize themselves with their location and avenues of approach, as well as special features and the purposes they will serve.

This will require several exploratory expeditions. Teachers find survey work very stimulating. Discovery of new material is constantly interesting. When a survey is made by a supervisory official and the teaching corps, it becomes an ideal project. The staff is divided into groups. Each group selects its leader and becomes responsible for a certain area. Reports are made by these groups at teachers' meetings, and the composite report furnishes the necessary data for the entire district.

The number of journeys will depend upon the importance of materials and their relationship to the curriculum. Lessons on or near the school plant can be conducted in the regular recitation period; those within easy access of the school, after school, or the last period of the morning or afternoon; if at some distance, on a Saturday morning or a holiday. Some journeys require an entire day. Proper arrangements should be made with the school authorities. For trips to museums,

public buildings, or industries, it will be necessary to make arrangements for guides, vehicles, etc.

School Journey Technique. The school journey, though highly valuable and a major visual aid, is but too rarely used. The reason is, perhaps, that teachers do not know school-journey technique. They too often fail to see the material which is close at hand; and possibly have not, in their teacher preparation, learned how to use it in instruction.

The following technique is recommended for organizing and conducting a school journey:

First step. Evaluate the advantages in order that as many as possible may be profitably utilized.

Second step. Determine the purpose for which the journey is to be conducted; or a possible combination of purposes.

Third step. Examine survey data for
- (1) Materials that will develop correct concepts.
- (2) Situations around which activities may be organized that will assist pupils in developing desirable attitudes, skills, and habits.

Fourth step. Make necessary arrangements with
- (1) School authorities.
- (2) Owners or representatives of places to be visited.

Fifth step. Initiating the journey.
- (1) Develop the need—during class discussion, or group activity, etc.
- (2) Have pupils definitely fix the aims.
- (3) Teacher preparation—familiarity with place, route, features, necessary reference materials.
- (4) Pupil preparation.
  - (a) Equipment—notebook, field glasses, proper clothing, etc.
  - (b) Study of reference material.
  - (c) Spirit of alertness, determination to meet and solve situations.

Sixth step. Instruction *en route* and the lesson.
- (1) On the way—pupils alert, at times noting and listing things seen; teacher a constant guide.
- (2) At the place—the definite lesson; pupils utilizing initiative, self-activity, observation, teacher guiding the organization of pupil observation.

(3) The return—pupils exchanging ideas, freely discussing experiences, asking questions, etc.

(4) The follow-up.
   (a) Reports from pupils.
   (b) Discussion of reports; questions by pupils and teacher; evaluating reports.
   (c) Coördination of the work.

Seventh step. Appraise the lesson.

(1) Teaching values.
   (a) Enriching and vitalizing.
   (b) Motivating.
   (c) Socializing.

(2) Constructive influence on pupils' attitudes, habits, and skills.

Dr. Armin K. Lobeck [1] of Columbia University makes the following practical suggestions pertaining to school journeys:

1. Do not spend too much time getting to the scene of action. The party must be fresh physically and eager mentally to discover what it is all about.

2. Do not crowd too much into a single afternoon. One good, rounded idea or combination of ideas is best. Concentrate on this and play it up in as dramatic a way as possible. Play with its facets. It is very likely that the ground will be familiar to most members of the group. They will think they know all about it. Startle them then by bringing out or having them discover what hitherto had been hidden from their understanding.

3. Members of the group must participate actively and not be passive listeners. They must have something to do, each one of them; pace off distances, determine locations, measure thicknesses of formations, look for boulders of a certain type, seek for fossils, note the character of the vegetation, or discover the typical occupation of the region, whether in buildings or farms. The pupils should make sketches, drawings, plans, maps, take pictures, and write descriptions.

4. Keep the whole proposition simple, or at least make it

[1] Lobeck, Armin K., "The Organization of Field Excursions," The National Education Association, Department of Elementary School Principals, *Thirteenth Yearbook, Aids to Teaching in the Elementary School*, 13:274–77.

seem so. Before leaving one place of observation, go over systematically all that has been observed, sum it up in typical form, and leave the job finished in shipshape fashion. Each member must feel that he has conquered the situation, that he understands it, and that there is nothing quite so interesting as to tackle another spot where this routine can be repeated.

SCIENCE SCHOOL JOURNEYS.

The school journey is indispensable to effective teaching of science. The following list is suggestive of the wide variety of possibilities in which the school journey would make science teaching more interesting and more meaningful.

(1) Visits to museums, zoological parks, and botanical gardens.
(2) Visits to chemical and other manufacturing plants.
(3) Visits to telephone buildings, aeroplane fields, radio stations, and power plants.
(4) Visits to engineering projects.
(5) Field trips to identify and classify animals and plants.
(6) Field trips to carry on studies of the interrelationships of species of plants and animals in certain limited areas.
(7) Visits to caves, gaps, and other interesting natural phenomena.
(8) Field trips to study agents of weathering and erosion at work.
(9) Astronomical observations of various heavenly bodies.
(10) Visits to ponds, lakes, streams, and bogs to study life.

Typical School Journeys. The following lessons in science which have been reported in the educational monograph, *Visual Education and the School Journey*, Department of Pennsylvania Instruction, Commonwealth of Pennsylvania, represent successful techniques in organizing and conducting school journeys.

A TRIP TO THE LOCAL PAPER MILL

Previous work:

The class has been discussing the making of paper.
(a) The materials—wood, rag, straw, etc.
(b) The processes involving science.

It was decided to visit the local paper mill to observe the application of science in the making of paper.

Arrangements for visit:

A committee from the class secured permission to visit the mill and arranged for the services of a guide who would explain everything connected with paper making.

Preparation:

The teacher visited the mill and studied the paper-making processes previous to the trip by the class.

The class was instructed to exercise extreme care when near moving or stationary machinery; to ask the guide reasonable questions regarding the materials, machinery, and processes; to give respectful attention to the guide when making explanations and to show appreciation for all courtesies and services.

At the mill:

The class was met by the guide, who first of all pointed out the logs of pulp wood piled in the yard.

GUIDE. From what kind of trees were these logs cut?

PUPIL A. They look like pine.

PUPIL B. I think they are hemlock.

GUIDE. They are spruce.

Upon entering the mill, the first object of interest was the *chipper* with its revolving knives. This machine breaks the wood into chips about one and one-half inches long.

The second process was then explained. The small chips passed from the chipper into the *digesters*. Here the chips are cooked with calcium bisulphate under steam pressure. The cooking dissolves the binding materials and leaves the pure cellulose fiber. This is called *pulp*.

From the digesters the group passed to the *cleaners*. As the pulp moves through the cleaning troughs, the cooking acid, undigested particles, and dirt are removed.

After being thoroughly cleaned, the pulp is subjected to the bleaching action of cloride of lime. This turns the pulp to a beautiful shade of white.

The next process takes place in the *beaters*. Through the rotation of the *beater roll* the fibers are so frayed that they lock together. Filler and sizing are added while the pulp is in the beaters.

PUPIL. What materials are used for filler?

GUIDE. Talc and china clay are used for fillers and liquid rosin for sizing. (The guide shows specimens of talc, china clay, and liquid rosin for sizing.)

After the beating process, the stock is passed through Jordon Refining engines and thence to the Fourdrinier machine where the

water passes off and the drying process takes place through drainage and evaporation.

It next passes through the *calender*, where the pulp in moving through a series of rolls is given the proper surface and finish. The paper is then wound into rolls and passed into the finishing room, where it is cut into different sizes and prepared for shipment.

Check:

Next day the following true-and-false test was given. This was to form the basis of discussion for the succeeding lesson.

(1) Jack pine and poplar trees are two of the woods used in making wood pulp.
(2) Pulp is formed by adding water to wood chips.
(3) All sawdust resulting from the wood chipping is used as fuel.
(4) In the digesters, the impurities are dissolved by chemicals.
(5) A Jordon machine makes the pulp into sheets of paper.
(6) Water is drawn from the paper pulp by means of suction.
(7) China clay and talc are the only fillers used.
(8) A mixture of rosin and sodium hydroxide is sometimes used in glazing the paper.
(9) Bleaching is caused by exposing the pulp to the sun.
(10) Small amounts of bark may be used in wood pulp manufacture.

A STUDY OF BIRDS

JUNIOR HIGH SCHOOL

I. Field Project, Study of Summer Birds
Locality, Northern Pennsylvania
Season, Summer Months

II. Committees appointed to take charge of trip:
A. Planning committee
B. Committee on what to look for
C. Supplementary committee
D. Final report committee

III. Plan:
A. A committee of pupils planned the trip. The class was organized into three groups of five students each. One group was to visit a local park; another, a nearby farm; the third, a wooded hillside.
Each pupil was requested to bring a pencil, notebook, and field glasses. Directions were given each group as to what they should observe.

At the end of a definite period of time, the leaders were expected to make a report of their respective groups. A supplementary committee was instructed to secure from books such information as could not be gathered on the trip.

B. What to look for:
   1. Kinds of birds
   2. Characteristics
      (a) Color
      (b) Size
      (c) Shape of head
      (d) Color of legs and feet
      (e) Formation of wing and tail
      (f) Peculiarities
   3. Behavior
      (a) Action when observed
      (b) Method of flight when seen
      (c) Does it run, hop, or walk while on ground?
      (d) Song
         (1) Musical
         (2) Unmusical
         (3) Varied
   4. Nests
      (a) Nests containing eggs
      (b) Nest containing young
      (c) Empty nests
      (d) Material of which nests are made
      (e) Location
   5. Importance to man

C. Summary of group reports.

The following narrative was reported from one of the groups:

As the note of a bird was heard one of the party exclaimed, "I wonder where it is?" We listened and found the song began with a trill and ended in a call. We continued slowly and finally found the bird perched on a wild cherry tree. We observed that its color was brown, brightest on the head, and thickly dotted on the breast and sides with darker brown heart-shaped spots. The throat was light in color. The bird was about eight inches in length: tail, nearly even; bill, long and brown. With a final burst of song he flew away. "What does he eat?" "What kind of nest does he build?" "What is it made of?" and "Are there eggs in it?" These were some of the questions asked about the little songster.

The class observed the following birds and a committee supplemented the field work from reference books in the library:

(a) Sparrow
(b) Gold finch
(c) Thrush
(d) Robin
(e) Crow
(f) King fisher
(g) Catbird

One group observed a nest in a thorn tree; another group found a nest in the crotch of an apple tree.

General knowledge of the birds seen was gained by the individual members of the class through the oral reports of each group.

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Chapter XI

Flat Pictures and Stereographs

THE term "flat pictures" is used for ordinary prints, photographs, and drawings in order to differentiate them from the stereograph.

Flat pictures speak a common language. Since the time of primitive man pictorial symbols have been used to represent objects and ideas. In fact, our alphabet and language were evolved from primitive pictorial symbols.

Flat pictures arouse interest with their concrete appeal. The modern teacher frequently uses pictorial illustrations to help in clarifying the meaning of some new device or idea. However, a flat picture is a substitute for reality and in this respect may have definite limitations which the teacher should be aware of:

(1) Flat pictures have but two dimensions. They lack depth, which sometimes gives the pupil wrong initial concepts.
(2) Flat pictures are frequently not true in color.
(3) Flat pictures are frequently not true in size.

These weaknesses in flat pictures should be recognized by the teacher and if possible corrected by the use of actual objects, school journeys, exhibits, or other more realistic visual aids.

Teachers should exercise care and good judgment when selecting pictures for classroom use. Good flat pictures for teaching purposes will have the following characteristics:

(1) Have one center of interest.
(2) Be true in color.
(3) Be true in size or have some familiar object in the picture by means of which the pupil can estimate size.

Since it is difficult to obtain a large number of pictures with all these qualities, the teacher should make every effort to supplement flat pictures with other improved visual aids.

MOUNTING PICTURES.

Pictorial materials such as postcards, photographs, textbook illustrations, and magazine illustrations are abundant. Flat pictures worth keeping for future lessons should be mounted, labeled, and possibly catalogued. The mounting material should be pliable enough to bend without breaking. A heavy quality of Cadmus cover paper makes very satisfactory mounting boards.

The color of the mounting paper is also important. The color of the paper should harmonize with the predominating tone of the flat picture. When in doubt about what color to use select a neutral color such as dull gray or a light coffee color.

It is desirable that some system be used in labeling, classifying, and cataloguing mounted pictures. Elaborate filing cases may be purchased, but these are not necessary. A case of shelves, a simple cabinet, or even cardboard boxes may be used for filing and storing flat pictures. Some teachers find large envelopes useful for this purpose.

BULLETIN BOARD.

There should be a large permanent bulletin board in every science classroom and laboratory. Its uses are many. On it may be placed photographs, diagrams, and clippings from magazines, newspapers, and books. It may be used as a place to exhibit exceptional work done by members of the class. It is also a good place for the teacher to post assignments and notices of club meetings. Bulletin boards are inexpensive and easy to make. A serviceable bulletin board may be made by tacking a piece of plain green denim over smooth pine or a piece of Celotex. A frame around the board will make it more attractive. Bulletin boards may also be made from Compo board. If several demountable bulletin boards are desired, fasten two window sash hooks to the backs of the boards. These hooks will enable you to mount the board on the blackboard or other molding which runs along the walls of your classroom. Thus different boards may be displayed when the

need arises and stored away again after they have been used.

Bear in mind the following suggestions pertaining to the care and use of a bulletin board:

(1) Promiscuous posting of pictures is not desirable. Pictures should be grouped together under unit or topic headings.
(2) Pupils should be encouraged to assume responsibility for the care and arrangement of the bulletin board.
(3) Care should be exercised in the length of time material is kept on the bulletin board. As a general rule it is desirable to remove materials from the bulletin board as soon as the topic or unit with which they were used is completed.

THE STEREOSCOPE.

The stereoscope is an individual optical instrument which makes surfaces appear as solids and which gives a realistic impression of depth and perspective.

Stereoscopes are usually of two kinds; a small, light stereoscope which can be held in the hand, and the telebinocular, a heavy mounted instrument for table use. (See figure 2.)

The hand stereoscope contains two lenses mounted in a frame and divided by a partition. The view with the left eye is thus separated from the view obtained with the right eye. The eyes are shielded from outside interference by a metallic hood which fits the facial contour snugly. A handle is provided for holding the stereoscope and a movable frame is fitted to the instrument for holding the stereograph.

The construction of the telebinocular is essentially the same as the construction of the small stereoscope, with the exception that the telebinocular is mounted on a heavy metallic base and is electrically illuminated. The telebinocular is usually placed on a table or desk in a convenient place in the classroom.

The stereoscope has a wide variety of uses. Several of its applications are in the fields of education, surveying, and internal or microscopic examination of objects. Impending applications lie in the direction of large scale stereoscopic projection and stereoscopic motion pictures.

The impression of reality which a student gains in the classroom through the use of the stereoscope and stereograph may awaken a latent interest in school subjects. Many schools are correlating subject matter with appropriate stereoscopic applications. Particularly in the science field the student often has difficulty in getting the correct impression needed—that of the life-like reality of third dimension.

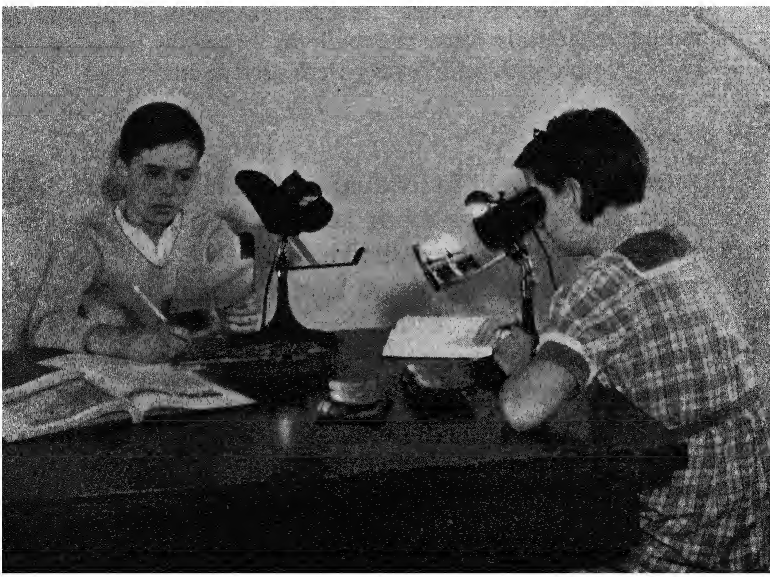

FIG. 2. Using a telebinocular. (Keystone View Co.)

A good example on the secondary school level is the teaching of physics. In teaching mechanics, considerable difficulty in expressing mechanical principles may be present, because of two-dimensional illustrations. If the student can see such illustrations in the third dimension, a greater appreciation of the principles of mechanics generally results.

Another example is the teaching of chemistry, where, like physics, a proper concept of the structure of the atom is needed. It is difficult to portray the structure of the atom in two dimensions, particularly on the blackboard. The use of

the stereoscope, because of its third-dimensional effect, will then greatly assist in the understanding of the structure of the atom.

The stereoscope is not only useful on the secondary school level but may be applied to the college classroom or laboratory as well. The stereoscope will assist in the appreciation of wave mechanics, in the study of polarized light, and in the study of astronomy. Stereographs may be made in these subjects and are of decided value in gaining the interpretation desired.

Aside from the schoolroom, there are other applications of the stereoscope (and the telebinocular). In medicine, a special stereoscopic X-ray machine enables the surgeon to locate foreign bodies in the human body. A stereoscopic X-ray machine may greatly aid in the extraction of bullets, bits of shrapnel, and other material from the bodies of wounded persons.

Industry is benefiting from the use of the stereoscopic principle. Defects in die castings, blow holes or slag inclusions in welded joints, imperfect structural beams, hair cracks in high pressure equipment, may all be accurately located. The stereoscope is used in the examination.

The layman in the future will probably undergo a series of rigid eye tests before obtaining a driver's license. In fact, several police departments are now using the telebinocular for determining visual-acuity defects and faulty depth perception which often lead to accidents.

Pilots of airplanes must now undergo a rigid stereoscopic eye test to determine whether they have perfect binocular sense. Accurate judgment of distance and accurate judgment of the relative size of objects and color are important in making safe landings and in maneuvering airplanes. The pilot must therefore have perfect binocular vision. Misjudgment of distance often leads to serious accidents.

The stereoscopic principles are now being applied to textbooks and even to motion pictures. Textbooks are being stereographically illustrated, and students are being supplied with suitable stereoscopes for viewing the books.

Teachers desiring more information on the principles of stereoscopy may refer to such a modern book as that by Arthur W. Judge.[1]

THE STEREOGRAPH.

The stereograph is a double photograph of an object or a scene (see figure 3). The photographs are taken with a stereoscopic camera which has two lenses. The two lenses are so arranged that one lens photographs the object or scene from an angle slightly to the left. The other lens photographs

FIG. 3. A stereograph. (Keystone View Co.)

the object or scene from an angle slightly to the right. The two photographs are mounted side by side on the stereograph. When viewed through a stereoscope the right eye sees more of the right side of the object and the left eye sees more of the left side of the object. In the brain the two images merge together giving us an impression of depth. "By means of these two different views of an object," as Oliver Wendell Holmes, the perfector of the stereograph, so vividly put it, "the mind, as it were, feels around it and gets an idea of solidity—and then we know it to be something more than a surface." Students frequently inquire how the brain fuses two pictures into a third with depth but there is as yet no adequate explanation

[1] Judge, Arthur W., *Stereoscopic Photography*, American Photographic Publishing Co., Boston, Mass.

of this amazing phenomenon of binocular vision. Nevertheless, the illusion of a third dimension created by the stereoscope adds charm and beauty to the photographs and gives the stereograph a position of preëminence among still pictures. In fact, one wonders why more science teachers do not become aware of the amazing potentialities of this visual aid. Stereographs and slides for use in general science, biology, physics, and chemistry may be obtained from the Keystone View Company.[1]

The following suggestions are offered as guides to the proper use of the stereograph:

(1) Study only a few views in each lesson. The stereoscope is individualistic and not meant for rapid group study.
(2) Have a sufficient supply of stereoscopes on hand.
(3) Most important of all is to make sure the stereographs have a definite connection with the lesson or subject to be studied.
(4) Follow up the use of the stereoscope with adequate discussion of the material covered.
(5) Slides of the same pictures on the stereograph may be used in collaboration with the stereographs.

The educational values that can be gained through the use of the stereoscope and stereograph are as follows:

(1) The illusion of reality produced by the stereoscope and stereograph makes a profound impression on the student.
(2) Slides can be used with the stereographs as supplementary material.
(3) Stereographs aid in reference reading and library work.
(4) Installation costs are quite reasonable.
(5) Stereographs are readily adaptable to the socialized type of recitation.

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[1] Keystone View Company, Meadville, Penna. Other addresses: New York; Chicago.

Chapter XII

Photography

THE camera opens up a number of possibilities to the resourceful science teacher. Pinhole cameras may be made by science classes and used to record experiences and scenes outside the school building. By means of the miniature camera and the motion picture camera, the science teacher may register scenes and action that are useful in teaching various phases of science. Microphotographs may be made by combining the microscope and the camera. Camera Clubs may be organized and with inexpensive materials make useful pictures of the immediate environment. The camera thus becomes an important help to the teacher of science.

Considerable interest has arisen in nature photography with the miniature camera. Pictures can now be taken in color and then projected on a screen by using special slides for the miniature camera film which is 35 millimeters in width. Two outstanding color films, Dufaycolor [1] and Kodachrome,[2] will be explained in this chapter in terms of general color photographic principles.

All photographic color processes may be divided into two classes: additive methods and subtractive methods. These are based on the Young-Helmholz theory of color vision. This theory assumes the existence of three nerve centers in the eye which are stimulated by red, green, and indigo-violet, the primaries from which all other colors are formed by a mixture of two or three of these in the eye.

Dufaycolor uses the additive process. The film contains thousands of tiny color particles which are sensitive to three primaries—red, green, and indigo-violet. A composite record of all the colors in the object photographed is obtained on the

[1] Dufaycolor, Inc., 30 Rockefeller Plaza, New York.
[2] Kodachrome, Eastman Kodak Companv. Rochester, New York.

same film. The time of exposure required is greater than for black-and-white photography.

Kodachrome uses the subtractive process. The film is coated five times. There are three layers of emulsions one for each of the primaries mentioned. A gelatin layer separates each of the photographic emulsions. The time of exposure is again longer than that required for black-and-white photography.

When using color films, no special fittings are needed for the camera or for the projector. The process of loading the camera with the films and taking the picture is just like that for black-and-white photography.

Nature photography is not seasonal, as is often supposed. The more somber and delicate hues of winter and autumn can be just as pleasingly recorded as the bright hues of spring and summer. It is best to remember that nature presents a pleasing arrangement of color unassisted by man.

The taking of pictures requires a first-hand knowledge of and experience with the elements of photography. There is, therefore, included in this chapter: (1) an elementary discussion of various kinds of cameras and (2) suggestions concerning techniques useful in taking pictures, developing negatives, and making prints.

CONSTRUCTION AND OPTICS OF AN ORDINARY CAMERA.

A photographic camera contains certain essential parts. The simplest type, the pinhole camera, consists chiefly of a cardboard box, approximately 4″ × 4″ × 3″, closed at the front except for a pinhole in the center of the face and a screen placed at the back for viewing the image. If the screen end is held to the eye and the camera pointed at an object such as a pole or a tree, the screen will receive an inverted and diminished image of the object.

The image produced by the pinhole camera may not be a clear one because of the diffraction of the light. If a double convex lens is substituted at the pinhole, a much clearer image will be obtained. As is natural with such a lens, this image will

also be inverted, but its size will be the same if the image is at the same place.

If the screen is replaced by a sensitive film or plate, the image may then be permanently recorded. This requires a back support, the "receptacle," for holding the film or plate. This combination is called a box camera and represents in action the principles of all cameras.

Modern devices such as the shutter and the diaphragm have been added to the box camera to clear up the distortion of the image, to aid the taking of a picture, and to cut down or increase the intensity of the light striking the film.

Some cameras have focusing scales for different object distances. Nearly all of them now have sensitive view finders which locate the image for the photographer and serve to insure a properly balanced picture.

TYPES OF CAMERAS.

Most of the cameras which a science teacher may use will be one or more of the following types:

1. *The Plate Camera.* This type of camera is essentially a folding camera with a special backing. A piece of frosted plate glass is held at the back in order that the photographer may view the picture. After the camera is properly adjusted, the frosted plate glass is removed and a special plate holder is inserted in the camera. The holder contains two sensitized glass plates for two separate exposures. The plates are exposed and ready for operation by the withdrawal of a sliding cardboard cover.

In nature photography the plate camera has desirable advantages from the standpoint of focusing but the cut-film and film-pack are displacing the use of the bulky glass plates. Cut-film may be used in the individual plate holders in place of the glass plates, but special adapters for holding each film are needed. These must be loaded and unloaded in a darkroom as with the glass plates. A film-pack contains twelve films which may be placed in or removed from the adapter in daylight, thus the number of pictures taken in daylight need not

be limited by the need of a darkroom for loading or unloading them. It is best to expose one film at a time and to refocus on the ground glass before each exposure.

2. *The Reflex Camera.* The reflex camera has the advantage of being able to give an image which is seen full size and right side up on the ground glass screen. This is handy for action photography. Essentially the construction of the camera is

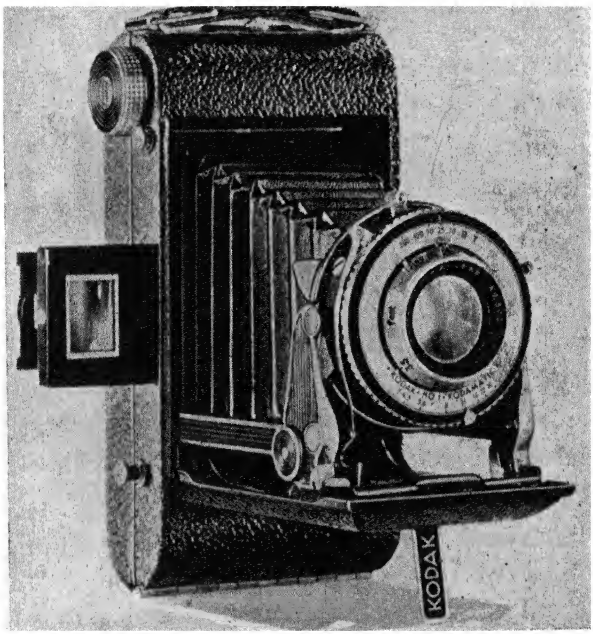

FIG. 4. A roll-film camera. (Eastman Kodak Co.)

the same as that of the plate camera except for a mirror inside the box. This mirror is set at an angle of 45 degrees behind the lens so the image formed by the lens is reflected right side up to the ground glass screen at the top of the camera.

When taking a picture with the reflex camera, the mirror swings up and out of the way and covers the ground glass screen. The exposure is then made by a special shutter which consists of a number of slits of different width and is known

as a "focal plane shutter," *i.e.*, it operates near the film or focal plane of the lens. To make the exposure, one of these slits passes in front of the film at high speed and the amount of exposure is thus controlled by the speed and the size of the width of the slit. A tripod is not needed for exposures, as it is needed by the plate camera just described previously.

3. *The Roll Film Camera.* A camera of this type is essentially the same as the box camera. However, it has a leather bellows in place of the wooden box, thus enabling the user to move

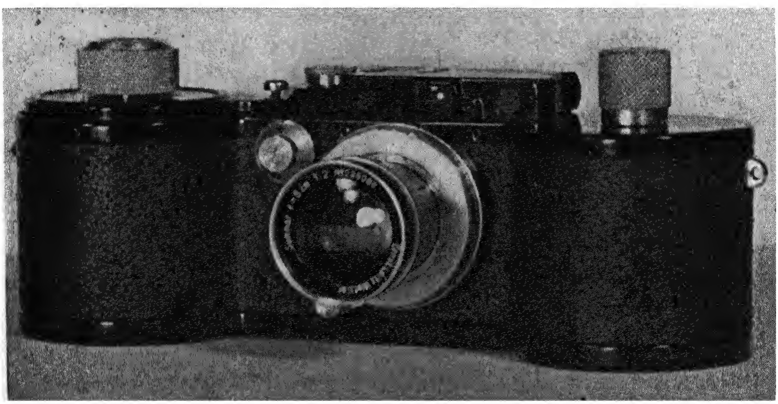

FIG. 5. A still-film camera. (E. Leitz Inc.)

the lens backward or forward for focusing or folding. The back contains two rollers, one at each extremity. One roller contains a roll of exposed film. After each picture is taken, a knob or key is turned on the outside and the film moved for a new exposure.

4. *The Miniature Camera* (Still Film Camera, Film Slide Camera). One of the newest developments in visual instruction has been the application of the miniature camera (still film or film slide camera) to the science classroom. The film (black and white) is, in reality, a positive film made from a negative film of standard width (35 mm.) containing a series of individual pictures or "frames." Such a film can thus be used where unity of study is needed for teaching and where it is an advantage to retain each picture on the screen for de-

tailed study. One application of this camera is given in several magazine articles by one of the authors in the references at the end of this chapter. The projection of still pictures *in color* by using the 35 mm. film between cover glasses as lantern slides has possibilities for the teacher interested in photography.

The Leica and Contax cameras are examples of miniature cameras using this film. Films from vest pocket sizes ($1\frac{5}{8}$ to $2\frac{1}{2}$ inches) down are generally considered miniatures and

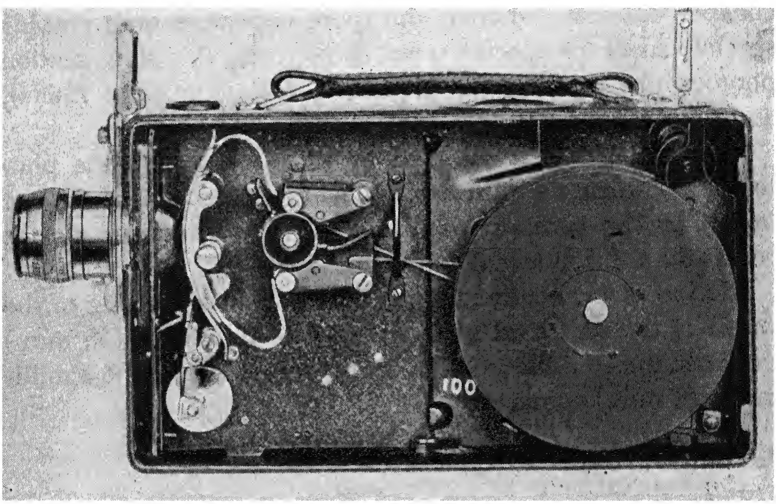

FIG. 6. The internal mechanism of a motion-picture camera. (Eastman Kodak Co.)

the cameras taking them are usually called miniature cameras. These cameras are inexpensive to operate, and easy to handle when properly studied beforehand. The miniature camera needs only one loading for several exposures. Shutter speeds may be set for $\frac{1}{100}$ sec., $\frac{1}{50}$ sec., $\frac{1}{25}$ sec., with proper setting of the diaphragm opening. Time exposures and bulb exposures which necessitate the use of a tripod are used mostly for indoor pictures. Usually an appropriate sighting device which requires no focusing is fitted to the camera. For field work in taking long-distance pictures a telescope device can be used.

5. *The Motion Picture Camera.* This type of camera is the one now being widely used for taking motion pictures. The construction of the motion picture camera may be simple or complex, depending on the amount of money paid for it. In simple construction the motion picture camera is similar to a roll film camera with the exceptions that a metal housing is used and reels of film supplant the rollers. Long strips of film are used, and many pictures are taken in rapid succession. The optical system may be of the simple type as found in cheaper cameras, whereas the more expensive ones employ special lenses for special types of pictures, *i.e.*, slow motion photography, technicolor pictures (employing color filters), and double exposure.

A crank handle is supplied by means of which the photographer turns the film rapidly, as the varied exposures are taken, or the camera may have a wind-up spring device which does this automatically when released.

Motion picture cameras may be classified according to the width of the film used in them: the 35 millimeter (35 mm.) cameras, the 16 millimeter (16 mm.) cameras, and the 8 millimeter (8 mm.) cameras.

TAKING PICTURES.

There is no royal road to taking a good picture. However, if one will observe the following simple rules, he should not experience much difficulty.

1. *Proper Lighting.* The amount and type of light necessary depend on many factors, particularly the kind of view, shadow effects, and whether the view is indoors or outside. Generally a book of rules is supplied with each particular camera and should be carefully read. Lacking this, an excellent treatise entitled *How to Make Good Pictures* may be obtained from the Eastman Kodak Company of Rochester, New York.

Keep in mind never to allow a strong light to strike the lens of a camera unless special effects are desired. If it is necessary to have the camera facing the light, as when taking

a photograph of an eclipse of the sun special color filters should be placed over the lens. Be careful that the light strikes the subject in such a way that shadow effects are produced, otherwise the picture will lack contrast. If one will look carefully into the finder before taking the picture, this difficulty may be avoided.

Photoflood bulbs placed in a desk lamp will serve as a good source of light for interior or night exposures without much expense. The lamps may then be placed in positions that will produce the best lighting effects. A picture taken with poor lighting or too much lighting is generally valueless.

2. *Sighting and Balancing.* An unbalanced picture is like a discord—the component parts are not harmonious. A balanced picture will have the right perspective and the proper depth of focus.

The extent to which the lens of a camera brings objects at different distances into sharp focus is termed *depth of focus.* Stated another way, depth of focus is the distance in front and behind the object sighted in the finder within which details in the picture will be sharp and distinct. Within certain limits nearly all objects can be focused to reasonable sharpness, but should the camera be focused on a near object, the distant objects are then likely to be out of focus. This is possible in a universal focus camera.

Look into the finder and make sure the image seen there contains all or more of what you want to photograph. Sometimes it will be impossible to get everything. Hold the camera level, or support it on a tripod. Do not tilt in any direction unless special effects are desired. Place the camera the right distance away. With a box camera the lens is fixed and a distance of eight feet or more is generally taken. Should a folding camera be used, the lens may be moved for a wider range of view. In this case the object distance is usually determined, and the lens set accordingly.

The depth of focus will depend on two factors:

I. The focal length of the lens.
II. The opening in the diaphragm.

The depth of focus decreases with an increase in the size of the stop opening and the shorter the focal length of the lens of the camera the greater will be the depth of focus.

3. *Exposure.* Probably the most difficult feature of taking a picture is the determination of the duration of the exposure.

The duration of the exposure is determined by the following factors:

I. The intensity of light.
II. The nature of the subject.
III. The diaphragm opening or "stop."
IV. The sensitiveness of the plate.

Here again the science teacher should consult the technical data supplied with each camera. The monograph, *How to Make Good Pictures*, by the Eastman Kodak Company, will give helpful suggestions.

The diaphragm opening or "stop" must be given due consideration. Every camera is supplied with a diaphragm which consists chiefly of a number of metal blades opening out to a wide aperture and closing to a very small one by the action of a lever. It is readily seen that this is one means for controlling the time exposure.

There are two systems in use for marking the stops: (1) the "F" system used on all foreign cameras and nearly all American ones; (2) the "Uniform System" marked "U. S." on cheaper cameras.

In the "F" system, the number of a stop is obtained by dividing the focal length of the lens by the diameter of the opening. A lens with a focal length of eight inches (8 in.) if used with an aperture of ½ inch is designated in the "F" system as F.16. This may be designated also as F/16 or F:16.

Usually there are only a few stops marked on a camera. These are given in Table 3.

F/1.9	F/3.5	F/4.5	F/5.6	F/6.3	F/8	F/11
F/16	F/22	F/32	F/45	F/64		

The following table shows the relation of the "F" and

"U. S." systems, and the corresponding exposures on the basis of 1/25 of a second at F/16.

TABLE 3

"F" System	Exposure	"U. S."
4.5	1/400	1.26
5.6	1/200	2.
6.3	1/125	2.50
8.	1/100	4.
11.	1/50	8.
16.	1/25	16.
22.	1/12	32.
32.	1/6	64.

If too much exposure is given for a set stop, the picture will be overexposed and detail lost. Should not enough exposure be given, then the picture will be underexposed and again, not enough detail will result. This can often be avoided by running through a "test-film" first, taking the same picture at a fixed distance and with controlled lighting, yet varying the time of exposure. When developed, this test film will clearly show the proper time of exposure.

At present "light meters" are supplanting the use of "test-film." Light meters are of two kinds: optical and electrical. Light meters measure the light reflected from the object in front of the camera and thus give the information sought in exposure tables. Once the reflected light has been measured the setting of the opening of the diaphragm and the shutter speed (and sensitivity of film considered) are determined by a mechanical calculator just as in the table of exposures.

There are many optical exposure meters, some of them being named as follows: "Dremoscop," "Justodrem," "Gracoscop," "Lios," "Practos," "Bewi," "Diaphot," "Bell & Howell Photometer." In the Zeiss Ikon "Diaphot" one looks through a small window in the "Diaphot" and turns a disc slowly. This gradually darkens the whole picture. The setting is correct when the details in the shadows are just invisible. The scale then shows the correct aperture and shutter speed.

Optical exposure meters are convenient but they are liable to cause errors. Such errors are not due to the meter itself but to the eye, the sensitivity of which changes at times.

Electrical exposure meters or light meters give extremely accurate readings and are more constant than those made by the eye with the optical meters. A special type is the "Electro-Bewi" which combines both of these features, and thus one gets the values of both. These meters work very quickly; the right answer is obtainable as soon as they are pointed in the right direction.

Some examples of electrical light meters are as follows: "Photoscop," "Heliss," "Ombrux," "Metraphot," "Bewi," "Prinsen," "Rhamstein," and "Weston" (several models). In the electrical exposure meters the light reflected from the object is transformed into a weak electric current by a sensitive "light cell" or photoelectric cell. A microammeter or moving coil galvanometer registers this variation in current on a scale which has been calibrated. The pointer gives at once the correct exposure time.

TECHNIQUE OF DEVELOPMENT.

After the exposure has been made, the plate or film is removed from the camera and developed.

Let us recall here the essential chemical reaction which has taken place during exposure. The film contains a "base" (a substance similar to celluloid) upon which has been placed an emulsion that holds particles of a silver salt in colloidal suspension. On exposure the light strikes the emulsion and produces a chemical change in the silver salt, thus forming a hidden or latent image.

There are certain solutions that change the silver salt which has been affected by the light, reducing it to metallic silver. These solutions are called "developers." By placing the film in a developing solution the hidden image is brought out. The image is, however, reversed. The white parts of the object appear black on the film whereas the black parts appear white.

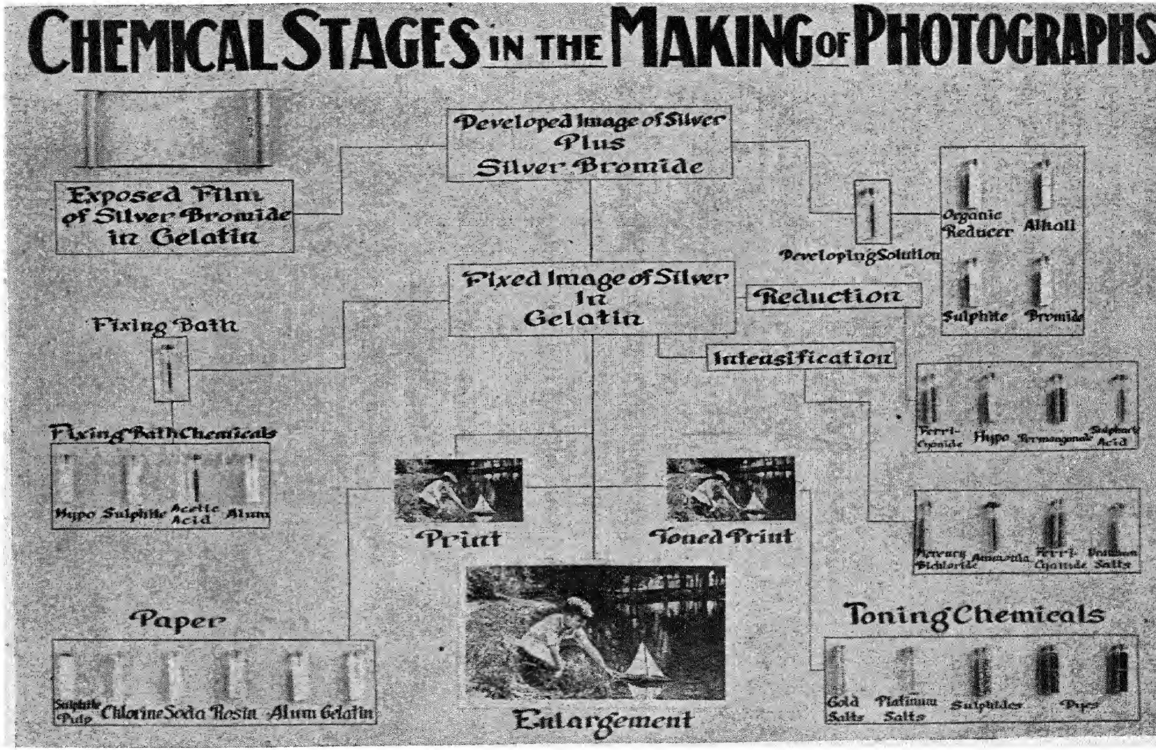

FIG. 7. The chemistry of photography. (Eastman Kodak Co.)

Some teachers find the use of prepared developers more convenient than making up the developing solutions, and different kinds of film may require different developers. The directions supplied with different films should be carefully read and observed.

Formulas DK–50 [1] and D–61A are especially recommended for general portraiture or commercial work. They produce negatives of average contrast, free of stain or fog and have advantages over "pyro" in that it is possible to duplicate the results easily, whereas with a "pyro" developer, the degree of stain and, hence, the printing contrast tends to vary from batch to batch of negatives.

Those preferring developers will find very satisfactory results can be obtained from Formulas D–1 and D–7. These developers, however, have much poorer keeping properties than any of the elon-hydroquinone developers.

Lantern Slides. Formula D–34 gives pleasing black tones and formula D–32 warm black tones. D–32 is especially recommended for Eastman Slow Lantern Slides.

FORMULA D–61A

Elon-Hydroquinone

(For general tray or tank use)

Stock Solution	Avoirdupois	Metric
Water (about 125° F.) (52° C.)	16 ounces	500.0 grams
Elon	45 grains	3.1 grams
Sodium sulphite, dessicated (E. K. Co.)	3 ounces	90.0 grams
Sodium bisulphite (E. K. Co.)	30 grains	2.1 grams
Hydroquinone	85 grains	5.9 grams
Sodium carbonate, dessicated (E. K. Co.)	165 grains	11.5 grams
Potassium bromide	24 grains	1.7 grams
Cold water to make	32 ounces	1.0 liter

(Dissolve the chemicals in the order given)

For tray use: Take 1 part of stock solution to 1 part of water. Develop for about 7 minutes at 65° F. (18° C.).

For tank use: Take 1 part of stock solution and 3 parts of water. At a temperature of 65° F. (18° C.) the development time is about 14 minutes.

[1] *Book of Formulas for Eastman Professional Films and Plates.* Eastman Kodak Company, Rochester, N. Y., July, 1936.

While this developer does not produce negatives of warm tones they have good printing density and quality and the developer has excellent keeping properties. It is one of the most satisfactory developers for continued use and, when kept up to normal volume, will give good results over a period of several weeks.

FORMULA DK–50

Kodalk Developer

(For normal contrast on professional films and plates)

	Avoirdupois	Metric
Water (about 125° F.) (52° C.)	64 ounces	2.0 liters
Elon	145 grains	10.0 grams
Sodium sulphite, dessicated	4 ounces	120.0 grams
Hydroquinone	145 grains	10.0 grams
Kodalk	1 oz. 145 grains	40.0 grams
Potassium bromide	29 grains	2.0 grams
Cold water to make	1 gallon	4.0 liters

(Dissolve the chemicals in the order given)

For tank use: Develop 4 to 7 minutes at 65° F. (18° C.) in the fresh developer according to the contrast desired.
For tray use: Decrease the time about 20%.

Greater or less contrast may be obtained by developing for longer or shorter times than those specified.

By increasing or decreasing the quantity of Kodalk in the formula it is possible (a) to increase or decrease the contrast obtained in a given time of development, or (b) to decrease or increase the development time without affecting the contrast. For example, by doubling the Kodalk, the time of development will be decreased by one-third.

FORMULA D–34

Elon-Hydroquinone Developer

(For lantern slides. Blue-black tones)

	Avoirdupois	Metric
Stock solution A		
Water (about 125° F.) (52° C.)	16 ounces	500.0 cc.
Elon	60 grains	4.2 grams
Sodium sulphite, dessicated	½ ounce	15.0 grams
Hydroquinone	½ ounce	15.0 grams
Cold water to make	32 ounces	1.0 liter

FORMULA D-34—*Continued*

	Avoirdupois	Metric
Stock solution B		
Water	32 ounces	1.0 liter
Sodium carbonate, dessicated	½ ounce	15.0 grams
Potassium bromide	30 grains	2.1 grams

(Dissolve the chemicals in the order given)

For use: Take stock solution A, 1 part, stock solution B, 1 part.
For softer tones: Take equal parts of A, B, and water.
Develop 1½ to 3 minutes at 70° F. (21° C.).

FORMULA D-32

Hydroquinone-Caustic Developer

(For lantern slides. Warm black tones)

	Avoirdupois	Metric
Stock solution A		
Water (about 125° F.) (52° C.)	16 ounces	500.0 cc.
Sodium sulphite, dessicated	90 grains	6.3 grams
Hydroquinone	100 grains	7.0 grams
Potassium bromide	50 grains	3.5 grams
Citric acid	10 grains	0.7 grams
Cold water to make	32 ounces	1.0 liter
Stock solution B		
Cold water	32 ounces	1.0 liter
Sodium carbonate, dessicated	1 ounce	30.0 grams
Sodium hydroxide	60 grains	4.2 grams

(Dissolve the chemicals in the order given)

For use: Take equal parts of A and B. For still warmer tones take 1 part A and 2 parts B.
Develop about 4 to 6 minutes at 70° F. (21° C.).

The film or plate should be handled with care to prevent light from spoiling the picture. It should be removed from the camera in a darkroom equipped with a "ruby" light. First the film or plate is washed with cool water in a tray. Then it is placed in the developing solution and moved back and forth constantly to insure even development.

After development, the film or plate should be thoroughly washed with cold water and placed in the "hardening" or "fixing" bath. This is a "Hypo" solution consisting chiefly of sodium thiosulphate, which dissolves all the unchanged silver compounds in the emulsion. In a short time, the film or plate is removed and thoroughly dried. The picture is now "fixed" and is called a negative.

A standard formula [1] for making such a "Hypo" fixing bath is herein given:

FORMULA F-5

ACID HARDENING FIXING BATH

(For general use with films and plates)

	Avoirdupois	Metric
Water (about 125° F.) (52° C.)	80 ounces	2.5 liters
Sodium thiosulphate (Hypo)	2 pounds	960.0 grams
Sodium sulphite, dessicated	2 ounces	60.0 grams
Acetic acid * (28% pure)	6 fluid ozs.	190.0 cc.
Boric acid, † crystals	1 ounce	30.0 grams
Potassium alum	2 ounces	60.0 grams
Cold water to make	1 gallon	4.0 liters

(Dissolve the chemicals in the order given)

* To make 28% acetic acid from glacial acetic acid, dilute three parts of glacial acetic acid with eight parts of water.

† Crystalline boric acid should be used as specified. Powdered boric acid dissolves only with great difficulty and its use should be avoided.

Films and plates will be fixed properly in 10 minutes if a freshly prepared fixing bath has been used. Leaving them in the solution for a few minutes longer than the time specified will not do any harm, but prolonged immersion, especially in warm weather, is harmful.

When the total fixing time (twice the time to clear) for a slow-fixing film or plate, exceeds 20 minutes, the bath should be discarded. This will occur after approximately eighty to one hundred 8 × 10 inch films or plates or their equivalent have been fixed per gallon (4 liters). The bath gives good hardening and should not sludge throughout its useful life.

SOME COMMON ERRORS TO BE AVOIDED.

(1) Make sure the red light used is deep red.
(2) Solutions should be kept in glass bottles tightly stoppered and at normal temperature. If solutions are too hot when used, streaking will occur. Cold solutions increase the time required for development.
(3) Wash the trays thoroughly after using as they easily become contaminated. See formula given for cleaning trays.

[1] *Book of Formulas for Eastman Professional Films and Plates*, Eastman Kodak Company, Rochester, New York, July, 1936.

(4) A negative will be overdeveloped if allowed to remain in the developer too long and will be underdeveloped if not long enough. When developing the "test film" be sure to note the time required for its development.

(5) All negatives should be thoroughly washed before they are dried to prevent them from curling up and from fading.

FORMULA TC-2

ACID PERMANGANATE TRAY CLEANER

(For removing silver stains)

	AVOIRDUPOIS	METRIC
Solution A		
Water	32 ounces	1.0 liter
Potassium permanganate *	73 grains	5.0 grams
Sulphuric acid, C. P.*	2½ drams	10.0 cc.
Solution B		
Water	32 ounces	1.0 liter
Sodium bisulphite	145 grains	10.0 grams

Pour solution A into the tray and allow it to remain for a few minutes, then rinse with water. Apply solution B, and wash thoroughly.

* Add the sulphuric acid slowly while stirring the permanganate solution rapidly.

This formula is recommended especially for the removal of several types of silver stains from enamelled trays. It is also satisfactory for general use.

TECHNIQUE OF PRINTING.

The negative is used for making a positive or print. The emulsion side of the film is placed against a piece of printing paper which has been treated with a sensitive emulsion in the same manner as the film. When the combination, in a printing frame, is held to a light source, the light passes through the various parts of the negative, striking the paper in varying amounts. This brings about a chemical change similar to the change that was produced on the negative. This paper is then developed and fixed as was the negative. The developing solution for the print paper should be the one recommended by the maker. These instructions may be found on the direction sheet supplied with the print paper.

It is best to run through a "test strip" of print paper before the real positives are made. Save the odd strips of print paper which result from the cutting of the paper to fit the negative.

The procedure to be followed here is exactly the same as that used for the real positives. Place the strip of print paper back of the negative in the printing frame and expose parts of the strips for different intervals of time. When this is first developed the photographer has a fairly accurate determination of the proper amount of exposure needed for the positive.

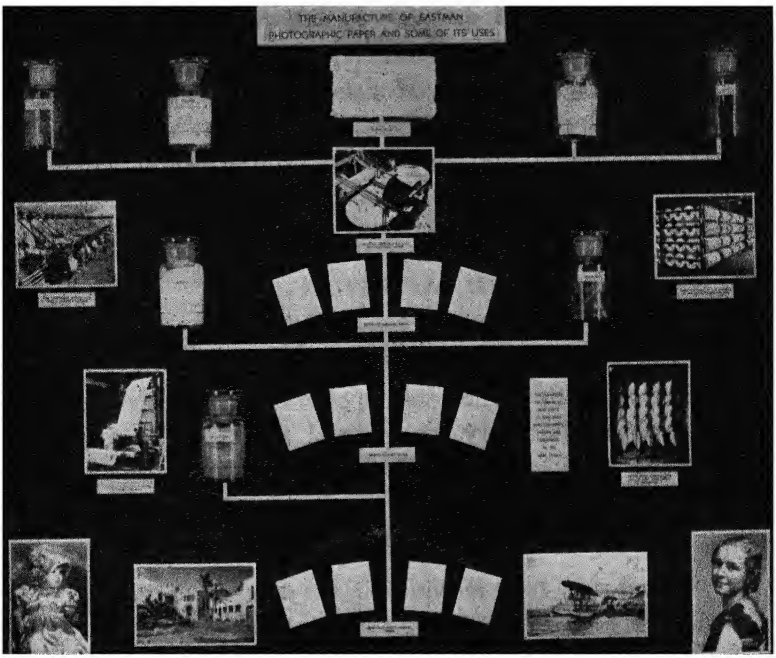

FIG. 8. How photographic paper is made. (Eastman Kodak Co.)

Place the strip in the developing solution until properly developed. Remove it and thoroughly wash it with water. Place the printing paper now in the rinsing solution and allow it to remain for a while. When ready to fix, put the strip in the fixing solution Formula F–5 given previously. After fixing properly, remove the strip, thoroughly wash with water and dry. The paper is then called a positive.

The same common errors may result here and it would be advisable to follow what has been recommended in this re-

gard in the discussion on "Technique of Development" just previously given.

FORMULA SB-1

ACETIC ACID RINSE BATH

	AVOIRDUPOIS	METRIC
Water	32 ounces	1.0 liter
Acetic acid * (28% pure)	1½ fluid ozs.	48.0 cc.

* To make 28% acetic acid from glacial acetic acid, dilute three parts of glacial acetic acid with eight parts of water.

This bath is recommended for use with photographic papers between development and fixation. Its action immediately checks development and prevents staining troubles. Move and separate prints while in the rinse bath to insure thorough access of the solution to all parts of every print.

THE SCHOOL DARKROOM LABORATORY.

Many science teachers are handicapped because of the lack of appropriate space for a really efficient darkroom. But nearly any nook or corner can be converted into a serviceable photographic laboratory for general needs. Not much expense need be incurred. The equipment can be obtained very reasonably provided the teacher knows what to select, which may include the following essentials:

(1) A good ruby light for vision in the dark without harm to the film or plate. An ordinary red 110 volt (110 v.) bulb may be used if further protection is given to it. A piece of red cellophane can be used and simply wrapped around the bulb or placed at openings in a cardboard box used as a shield.
(2) Inexpensive good enamelware or glass baking pans may be used for developing. At least three may be needed. These may be obtained in various sizes and will be determined by the space available. Visit your local five-and-ten-cent store.
(3) A few glass-stoppered bottles may be used for keeping the solutions. The size of the bottles will depend on how much solution is made or procured. The bottles should be labeled.
(4) Paper clips strung on a wire overhead may be used to hold the prints and negatives while drying.
(5) Shoe boxes or empty cigar boxes may be used to keep the printing paper intact and to store odds and ends such as scis-

sors, clips, or strips of paper, which accumulate around the darkroom laboratory.

SOURCES OF PHOTOGRAPHIC EQUIPMENT

Plate Cameras and Reflex Cameras

Eastman Kodak Company, Rochester, N. Y.
"Fothiflex," Camera Specialty Co., Inc., 1199 Broadway, New York.
"Graflex," Folmer-Graflex Corp., Dept. A-2, Rochester, N. Y.
"Primorflex," Mimosa American Corp., 485 Fifth Ave., New York.
"Rolleiflex," Burleigh Brooks, Inc., 127 W. 42 St., New York.

Roll Film Cameras

Eastman Kodak Company, Rochester, N. Y.
E. Leitz, Inc., 730 Fifth Ave., New York.

Miniature Cameras (Film Slide)

"Agfa," Agfa Ansco Corp., Binghamton, N. Y.
"Argus," International Research Corp., 194 Fourth Ave., Ann Arbor, Michigan.
Eastman Kodak Company, Rochester, N. Y.
"Exakta," Photo Marketing Corp., 10 W. 33 St., New York.
Folmer-Graflex Corp., Rochester, N. Y.
"Leica," E. Leitz, Inc., 730 Fifth Ave., New York.
Medo, 15 West 47 Street, New York.
"Parvola," Henry Herbert, 483 Fifth Ave., New York.
"Zeiss Ikon," Carl Zeiss, 485 Fifth Ave., New York.

Motion Picture Cameras (16 Mm.)

Agfa Ansco Corp., Binghamton, N. Y.
Bell & Howell Company, 1801 Larchmont Ave., Chicago, Ill.
Eastman Kodak Company, Rochester, N. Y.
Herman A. DeVry, Inc., 1111 Center St., Chicago, Ill.
International Projector Corp., 90 Gold St., New York.
Victor Animatograph Corp., Davenport, Iowa.

Enlargers

Chess-United Co., Emmett Bldg., 29 St. & Madison Ave., N. Y.
Elwood Pattern Works, Inc., 125 N. East St., Indianapolis, Ind.
Simmons Brothers, 37–06–36 St., Long Island, N. Y.

Light Meters

Weston Electrical Instrument Corp., 613 Frelinghuysen Ave., Newark, N. J.
Bell & Howell Company, 1801 Larchmont Ave., Chicago, Ill.

FILM SLIDES

Cambosco Scientific Supply Co., Waverly, Mass.
Chicago Apparatus Co., 1735 N. Ashland Ave., Chicago, Ill.
Ideal Pictures Corp., 30 East 8 St., Chicago, Ill.
Society for Visual Education, 327 S. LaSalle St., Chicago, Ill.
U. S. Department of Agriculture, Washington, D. C.
Williams Brown & Earle, 918 Chestnut St., Phila., Pa.
W. M. Welch Scientific Company, 1516 Orleans Ave., Chicago, Ill.

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Chapter XIII

Objects, Specimens, and Models

A GOOD science teacher makes provision for the pupil to see and handle materials at the right time. Effective teaching requires the choosing of the right details and the seizing of the psychological moment to make these materials stand out and serve in the process of instruction. Effective teaching stimulates a spirit of inquiry and industry in pupils and arouses in them a desire to solve problems and to achieve results.

Objects, specimens, and models offer exceptional opportunities to the resourceful science teacher. In fact it is very doubtful whether effective science teaching can be achieved without a liberal use of these visual aids.

OBJECTS. An object is the thing itself—for example, a bird, a frog, a grasshopper, a flower, a barometer, and the many other things which are brought into the science classroom and laboratory for study.

Objects are ideal visual aids. They are the things themselves; they are reality and not a substitute for reality. Objects are preferred in science teaching whenever it is possible to obtain them, because they put the pupil in direct contact with actual things and relationships. They provide the means for establishing correct initial concepts in the minds of the pupils.

SPECIMENS. A specimen is a sample or a part of an object, for example—a piece of coal, a piece of marble, the skin of a bird, a leaf, or a piece of mineral. Depending upon how it is used in teaching a thing may be an object or a specimen. An actual monarch butterfly if it were used by a biology teacher to represent all butterflies would be a specimen. However, if the monarch butterfly were used to study only the characteristics of the monarch butterfly it should then be classified as an object.

Specimens are excellent visual aids for science teaching but they are not quite as valuable as objects. Since they are only a sample or a part of an object they cannot stimulate as complete a sensory experience as do objects.

MODELS. A model is a replica of something. It may be a representation in miniature—for example, a small model

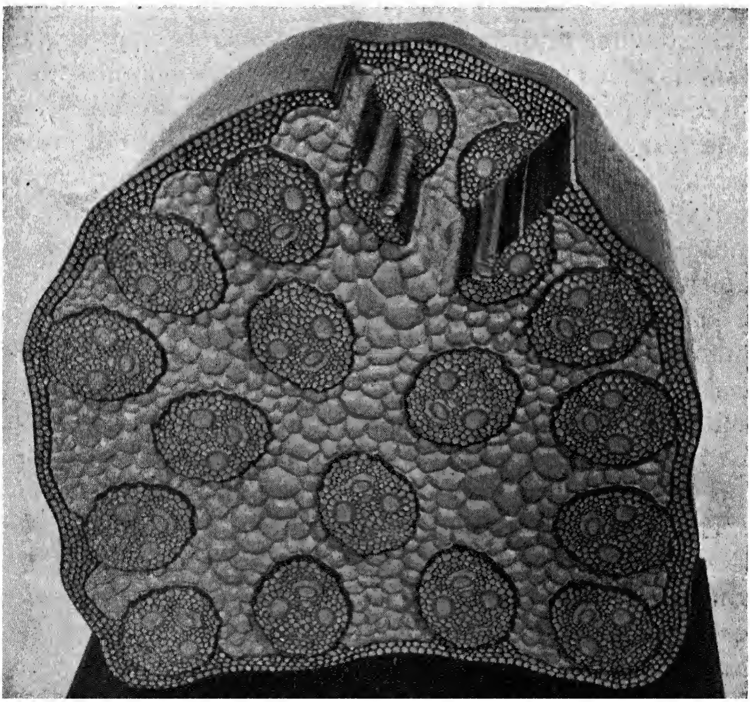

FIG. 9. Model of cross-section of a corn stem.
(Jewell Model Co.).

of the working parts of an automobile or it may be a representation in enlargement such as a model of a paramecium or a model of a hydra.

Models are very helpful to science teachers, but they also have their limitations. Models generally are not true in size or color. If a biology teacher employs a model of a paramecium incorrect concepts may be formed in the minds of the pupils about the paramecium unless provision is made in

some way to overcome the psychological limitations of the model

MUSEUMS. One of the chief aims of science teaching is to make children intimately acquainted with the nature of the world in which they live; to teach them to understand and appreciate the interrelationship between man and his environment. Children cannot gain such appreciation and understanding of their surroundings by merely reading about things; it must come through observation and handling them.

Observing objects and phenomena in their natural setting is the ideal way to gain knowledge. However, with our present system of mass education this is not always possible or feasible. It becomes exceedingly important, then, that we bring the outside world into the classroom and laboratory through exhibits and other concrete representations of things.

The science department of every school should begin a museum. There is a wealth of material within the reach of nearly every school. The natural instinct for collecting and hoarding which many children seem to have should be utilized for building up the museum as well as for motivating and vitalizing the subject matter of science courses.

The following list of topics is indicative of the great variety of specimens and objects from our world of living things which may be collected for the school museum; butterflies, moths, other adult insects, frogs, toads, snakes, turtles, salamanders; birds' nests, cocoons, larvae of insects, leaves, stems, fruits, roots, grasses, flowers, bark, tubers, bulbs, corms, mushrooms, lichens, and seeds.

Other sources of museum materials are as follows:

1. *Public Museums.* Science teachers should investigate nearby museums to determine whether any exhibits of specimens may be borrowed, rented, bought, or obtained for permanent use free of charge. Exhibits of raw materials such as latex, flax, wool, silk, cotton, and food stuffs may be obtained at a low cost from the Commercial Museum, Philadelphia.

2. *Homes.* Teachers should encourage pupils to bring things from home which will serve to illustrate lessons. House-

hold utensils, gadgets of various kinds, pictorial materials, books, etc., useful for a museum may be obtained in this way.

3. *Local Stores and Industries.* Excellent museum materials may sometimes be obtained free from local stores and local industries or purchased at a low cost from stores such as five-and-ten-cent stores.

4. *Butcher Shops and Slaughter Houses.* These are good places for biology teachers to find anatomical specimens.

5. *Scientific Supply Houses.* The following companies specialize in supplying objects, specimens, and models to schools. Science teachers should write to these firms for free catalogues.

Biological Supply Co., 1176 Mt. Hope Ave., Rochester, N. Y.
Cambridge Botanical Supply Co., Waverly, Mass.
Carolina Biological Supply Co., Elon College, N. C.
Central Scientific Co., 460 E. Ohio St., Chicago; 220 E. 42nd St., New York; 1121 S. Hill St., Los Angeles, Calif.; 79 Amherst St., Boston, Mass.
Chicago Apparatus Co., 1735 N. Ashland Ave., Chicago.
Clay-Adams Co., 25 East 26th St., New York (Models and charts).
Denoyer-Geppert Co., 5235 Ravenswood Ave., Chicago (Models and charts).
Empire Laboratory Supply Co., 559 West 132nd St., New York.
General Biological Supply House, 761–763 East 69th Place, Chicago.
Heil Corp., 210 S. Fourth St., St. Louis, Mo.
Kny-Scheerer Corp., 51–52 Twenty First St., New York.
Marine Biological Laboratory, Woods Hole, Mass.
Michigan Biological Supply House, 206 S. First St., Ann Arbor, Mich.
New York Biological Supply Co., 34 Union Square, New York.
A. J. Nystrom and Co., 3333 Elston Ave., Chicago (Charts).
Scientific Supplies Co., 123 Jackson Ave., Seattle, Wash.
Southern Biological Supply Co., 517 Decatur, New Orleans, La.
South-Western Biological Supply Corp., Dallas, Texas.
Standard Scientific Supply Corp., 12 W. 25th St., New York.
University Apparatus Co., 2229 McGee Ave., Berkeley, Calif.
Wards Natural Science Establishment, 302 N. Goodman, Rochester, N. Y.
W. M. Welch Scientific Co., 1515 Sedgwick St., Chicago.
Western Laboratories, 826 Q. St., Lincoln, Neb.

6. *Corporations.* Many corporations, as a part of their publicity and advertising campaigns, have prepared exhibits which are useful in teaching science. Some of these exhibits

may be obtained free of charge, whereas for others a small charge is made.

SUGGESTIONS AND HELPS FOR COLLECTING, PRESERVING, AND MOUNTING SPECIMENS

ANIMAL LIFE.

The collecting of specimens can be made an integral part of field trips. Although the observation of living plants and animals in their natural environment is the main objective of field trips, collecting interesting specimens and bringing them back to the laboratory adds zest and interest to the work. The specimens, after they have been observed and studied by the pupils, should be preserved and made a part of an evergrowing biology museum. The following table gives directions for killing and preserving the commonly used laboratory animals.

The formulas for the special preserving solutions are as follows: Bouin's fluid: saturated picric acid solution, 75 cc.; formalin, 20 cc.; glacial acetic acid, 5 cc.

Carl's solution: 95% alcohol, 170 cc.; formalin, 60 cc.; glacial acetic, 20 cc.; water, 280 cc. Do not add the acetic acid until just before using the solution.

Corrosive sublimate; concentrated solution. Do not mix in metal containers or stir with metal instruments, because they decompose the solution. Animals killed by corrosive sublimate should be washed carefully before being placed in alcohol.

Tellyesnicky's fluid: potassium bichromate, 3 gm.; glacial acetic acid, 5 cc.; distilled water, 100 cc.

The Care of Amoeba Cultures in the Laboratory. Protozoans of many kinds may be found in the stagnant water of ponds and ditches. Amoebae will nearly always be found on the undersides of lily leaves. Live cultures of amoebae may also be purchased from biological supply houses.

Amoebae are difficult to raise. The following points for maintaining amoeba cultures are recommended by the General Biological Supply House in *Turtox Service Leaflet No. 4:*

(1) Amoebae should be kept in shallow cultures. Water should never be more than one inch deep in the finger bowl.

(2) When the level of the water falls below this depth it is necessary to add water in very small quantities. Not more than a small pipette (medicine dropper) of pure distilled water should be added at daily intervals.

(3) Amoeba cultures should have a very small amount of food material present. Too much food material results in a too rapid increase of infusoria, which will crowd out the amoebae. A few ciliates, however, are not detrimental.

(4) If no wheat or hay is present in the culture when it is transferred to the finger bowl, add two pieces of boiled timothy hay stems, each one inch long, or if no timothy is available, three grains of boiled wheat.

(5) By placing the finger bowl on the stage of a binocular microscope, the relative number of amoebae present in the culture can be determined easily. Observe it from time to time; if the infusoria become too abundant it is probable that too much food is being used.

(6) If the amoebae become abundant the culture may be divided. To reculture proceed as follows:

Stir the culture well and pour into another clean finger bowl; then pour half of the water back into the old finger bowl. To each culture add two pieces of boiled timothy hay stem, one inch long, and cover cultures with glass plates. Every other day add a small pipette of pure distilled water to the culture. In this way bring the water level up to a depth of one inch. Check the progress of the culture by viewing it occasionally through the binocular microscope. These cultures should continue to flourish for a long time. After several weeks they may be recultured by following the same procedure.

Feeding Aquarium and Terrarium Animals. To be successful in keeping live animals in the laboratory requires patience and care. The busy teacher should allow the more interested members of her class to take over the responsibility of caring for the animals kept in the classroom or laboratory. Before this is done, however, the teacher should be certain that the pupils know the life habits (especially the feeding habits) of the animals assigned to their care.

Animals kept in captivity must frequently be trained to eat. Much time and patience is sometimes required at first to get

TABLE 4

THE COLLECTION AND PRESERVATION OF SOME OF THE COMMONLY USED LABORATORY ANIMALS *

ANIMALS	WHERE FOUND	SPECIAL COLLECTING TOOLS	HOW TO KILL	FIXATIVE	PRESERVATIVE
Fresh-water sponges	Midsummer in fresh water attached to branches and submerged wood.	Flat-bladed knife or scalpel.	70% alcohol changed when it becomes discolored.	70% alcohol.	70% alcohol.
Hydra	Lagoons, ponds, rivers, lakes attached to vegetation, stones, fallen leaves.	Flat-bladed knife or scalpel and pipette.	Hot Bouin's flooded over specimens from base to peristome.	Bouin's.	70% alcohol.
Fresh-water Planaria	Fresh spring-fed streams, lakes, rivers.	Fresh beef or liver placed in water where Planaria are found.	Extend on glass plate and submerge in hot Gilson's or corrosive sublimate.	Gilson's or corrosive sublimate.	Formalin or alcohol.
Tapeworms	Intestines of dogs, cats, rabbits, or sheep.	Scalpel and forceps.	Extend on blotting paper saturated with fixative	Bouin's or formalin.	Alcohol or formalin.
Ascaris	Intestines of pigs, horses, cats, or dogs.	Scalpel and forceps.	Water heated to 98° C. Worms dipped momentarily.	5% formalin or saturated corrosive sublimate solution.	5% formalin or alcohol.
Rotifers	Plant material taken from ponds or lagoons and placed in jar.	Pipette.	Anesthetize with solution of cocain hydrochlorate 1 gram—alcohol 12 cc., water 50 cc. Dilute to 3 × volume.	When cilia cease to move, add few drops osmic acid.	Wash in H_2O and store in 10% formalin.

* The General Biological Supply House, Chicago, Ill.

Pectinatella and plumatella	Attached to stems, rocks, leaves in streams, especially in late fall.	Scalpel.	When fully expanded, flood with boiling Bouin's.	Bouin's.	70% alcohol.
Earthworms	In spring on rainy nights on golf courses or blue grass lawns.	Flashlight and suitable clothing.	Anesthetize by slowly adding alcohol to water in which worms are placed. Lay out in pans and cover with formalin.	5% formalin.	5% formalin.
Leeches	Hand pick from hosts or with dip net among weeds in ponds and streams.	Dip net.	Anesthetize in warm chloretone or magnesium sulphate or asphyxiate in closed jar.	Inject with 10% formalin and submerge in same in extended position.	8% formalin.
Crayfish	Streams, ponds, lagoons in water or burrowed in mud.	Dip net, seine, or spade.	Drop alive into alcohol or 8% formalin.	70% alcohol or 8% formalin.	70% alcohol or 8% formalin.
Ticks and mites	Cattle, dogs, horses, old cheese, decaying organic matter.	White paper and brush for taking specimens from parasitized animals.	Drop directly into 70% alcohol.	70% alcohol.	70% alcohol.
Centipedes and millipedes	Under logs or stones.	Forceps.	Carl's solution.	Carl's solution injected into body cavity	Carl's solution.
Insects	Woods, fields, water, air—everywhere.	Nets, forceps, and other equipment depending on kind collected.	For drying, in killing jar. For liquid preservation, in alcohol.	Alcohol, Carl's solution, chloral hydrate, and special solutions.	Alcohol, Carl's solution, or drying.

TABLE 4—*Continued*

THE COLLECTION AND PRESERVATION OF SOME OF THE COMMONLY USED LABORATORY ANIMALS—*Continued*

ANIMALS	WHERE FOUND	SPECIAL COLLECTING TOOLS	HOW TO KILL	FIXATIVE	PRESERVATIVE
Slugs	In damp places under leaves, logs, stones, etc.		Anesthetize in boiled water (cooled) and immerse in formalin or alcohol.	Alcohol or formalin.	70% alcohol or 8% formalin.
Aquatic snails	Streams, ponds, lagoons, lakes. Most abundant among vegetation.	Dip net, scraper net.	Anesthetize in warm water by adding magnesium sulphate, causing them to expand, then drop into 10% formalin.	10% formalin.	8% formalin.
Clams	Streams, lakes, partly buried in the bottom.	For large numbers a dredge or crowfoot hooks are used.	Place wooden pegs between the two halves of shell and drop into 10% formalin.	10% formalin.	8% formalin.
Lampreys	Occasionally may be taken from fish, but for large numbers must be taken in breeding season in streams.	Seine.	Remove from water for few minutes and inject 10% formalin in body cavity.	10% formalin.	8% formalin.
Fishes	Streams, lakes.	Nets, seines, or hook and line depending on kind.	Drop into full strength formalin.	10% formalin.	8% formalin.
Grassfrogs	In meadows or borders of marshy lakes.	Net.	Inject ether into body cavity or drop into 80% alcohol.	Inject 5% formalin into body cavity and place in 5% formalin.	5% formalin.

Grassfrog eggs	Shallow water of ponds in early spring when singing is started.		Place in fixative.	8% formalin or Tellyesnicky's.	8% formalin.
Salamanders	Damp places in woods, ponds, rivers, streams, sloughs.	Hook and line or nets depending on kind.	Inject ether into body cavity and drop into 8% alcohol.	5% formalin.	5% formalin injected into body cavity.
Reptiles	Woods, fields, dunes, depending on kind.	Snares for handling poisonous forms. Nets for capturing turtles and aquatic forms.	Inject ether into body cavity.	10% formalin.	8% formalin injected into body cavity.
Birds and small mammals	Most of world.	For taxidermy purposes a 12 gauge shotgun and shot shells with fine shot. (No. 8 or No. 12.)	Bird skins are generally used for study or reference purposes. Body is removed and skin dusted with arsenic powder. Skin is then stuffed with cotton, and dried.		

the animals to take their food. Cold-blooded animals (fish, frogs, toads, salamanders, reptiles, etc.) can go without food for long periods of time without harm. There is always more danger of overfeeding than underfeeding. The following suggestions [1] pertain to the food problems of common laboratory animals.

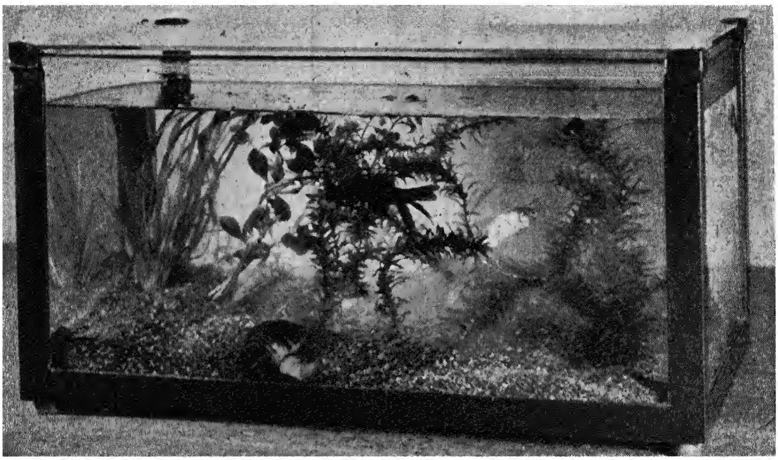

FIG. 10. A balanced aquarium. (Central Scientific Co.)

Snails. Snails relish fresh lettuce leaves and thrive on them. They also eat the algae in the aquarium tank (thus helping to keep the glass sides clear), aquatic plants, small pieces of meat, and powdered cuttle-fish bone. The last named is beneficial, as it develops their shells. In general, snails are scavengers, and if there are only a moderate number in a good-sized balanced aquarium, they will thrive without any special food or attention.

Snails found lying on the bottom of the tank with open operculum are dead and should be removed.

Fish. Fish demand a variety of foods, and the person who supplies them with a varied diet is sure to have the best results. Mix the diet with dried and live foods. If fish food is fed during the first part of the week, such living food as

[1] From *Turtox Service Leaflet No. 23,* General Biological Supply House.

enchytrae, daphnia, or chopped mealworms should be used during the latter part of the week. Fish may be fed shredded beef, chopped oysters or clams, earthworms, mosquito larvae, canned lobster or shrimp, cereals, mealworms, daphnia and other small crustaceans, yolks of hard-boiled eggs, and boiled or baked white potatoes. Live foods may always be had, for it is possible to rear mealworms, enchytrae, and daphnia in the laboratory, and earthworms can easily be kept on hand for use during the winter months.

Fish should be fed only every other day, or less often if the temperature is low. Overfeeding always causes more deaths than underfeeding.

Sickness among fish is common and is usually due to overcrowding, overfeeding, or the introduction of other sick fish to the tank. When a fish begins to act queerly, if white patches appear on its body or if its tail and fins begin to fray, it should immediately be removed from the tank, as most fish diseases are contagious. Salt baths in either table salt or epsom salts are good and may be given healthy fish monthly to insure permanent health. Prepare salt baths as follows:

3/4 teaspoonful table salt
1/4 teaspoonful epsom salts
1 gallon water

Fish may be left in this bath twenty-four hours without harm. For a half-hour treatment, use the same proportions, only use a tablespoon for measuring. New fish should be subjected to the salt bath treatment before being placed in an established aquarium, in order to guard against the introduction of disease.

Salamanders. The most common vivarium salamander is the red-spotted newt. It will live in a balanced aquarium or in a semi-aquatic terrarium, although over long periods it probably thrives best in the latter.

Newts may be fed living fruit flies, enchytrae, very small earthworms, pieces of mealworms, shredded beef, scrambled eggs, fresh liver, and the like. In an outdoor tank or pond

they will consume great quantities of mosquito larvae. If only one or two newts are to be cared for, they may be fed individually with pieces of food held with a pair of long forceps. However, if there are many, they should be fed living food or else transferred to a special dish for feeding, so that the aquarium will not be fouled by an excess of food.

Larger salamanders, such as Ambystoma, Triturus torosus, Phethodon, and Eurycea, live best in a semi-aquatic tank. Their food, however, is the same as that given above for the red-spotted newt.

Grassfrogs. The grassfrog or leopard frog must always be kept in a semi-aquatic condition so that he may take to or leave the water at will. If the frogs are kept cool this will slow down the metabolic processes and lessen the need for food. In nature, the frogs range in the grasses near the water and eat insects. In the laboratory this is hard to duplicate, but they will eat flies and other small insects dropped to them and, occasionally, they will eat small earthworms.

Tree frogs. Tree frogs should be kept in a semi-aquatic terrarium or in a woodland terrarium where there is plenty of moisture. They must have hiding places, such as clusters of ferns, mosses, small flowering plants, etc., where they can avoid the sun. In the average terrarium tree frogs will usually remain hidden during the day, coming out at night to feed. If food is provided during the day, however, they will soon learn to accept it.

Tree frogs live largely on insects and will take living Drosophila (fruit flies), mealworms, and roaches, all of which can be reared in the laboratory. Just release the living insects in the terrarium, and the frogs will soon find them.

Land turtles. Land turtles require warmth and sunshine, as well as some moisture. They drink much water and will become sick if they do not get enough. Their favorite foods are snails, slugs, maggots, over-ripe fruit (especially bananas), lettuce, carrots, and clover. They are not heavy eaters and often fast for long periods. Land turtles usually hibernate. If kept in a warm place in the autumn they will refuse food

and water and eventually die unless they are given a cool place in which to sleep for several months.

Their commonest illness is eye trouble, in which the eyelids become fastened down and covered with scales. The remedy is to bathe the eyes in a 3% boracic or salicylic acid solution several times a day. These animals also catch cold if left in a draft or if they live in too damp a place. This causes heavy breathing and loss of appetite and in extreme cases brings on death.

Aquatic turtles. Aquatic turtles find their food in swampy and moist places and then drag it into the water to eat. Therefore, it is wrong to try to feed aquatic turtles on land, as they need water to wash their food down with. Semi-aquatic conditions are needed for water turtles, as they do at times go up on land. Sand in one end is best, as this gives them a chance to bury themselves and avoid strong sunlight. They relish ground meats, fresh fish, tadpoles, mealworms, aquatic insects, and scrambled eggs, and at times some aquatic turtles will eat vegetative foods. Aquatic, as well as terrestrial turtles, go on long hunger strikes and refuse to eat. Force feeding is useless and usually does more harm than good. If mold appears on the shell, apply the same salt baths as given to fishes.

Lizards. Many lizards have cannibalistic tendencies. Therefore, it is not advisable to place too many species together.

They also have a strong fighting tendency and will do much jumping, hissing, and running when they are about to be caught. Anolis (chameleons) require much sunlight and heat, live in branches, and should be watered daily. The best way is to sprinkle the water on the branches and let them drink or lap it up as they would dew. Feed them roaches, flies, crickets, mealworms, and other living insects.

Horned "toads," which are lizards and not toads, require a high temperature (80–90° F.) if they are to eat. In winter place them near a radiator for several hours before attempting to feed them. They require a terrarium with several inches of dry sand on the bottom, as on cold days and nights

they like to bury themselves in the sand. Feed them mealworms, ants, cockroaches, and other living insects.

Alligators. Alligators require a semi-aquatic vivarium so that they may swim or sun themselves. They must have warmth (75–85° F.). They catch food in the sides of their mouths and drag it under water to swallow. Feed by dangling food to one side of their nose and they will soon snatch at it and swim away with it. They eat fresh beef, liver, scrambled eggs, mealworms, tadpoles, cockroaches, and fish.

Snakes. The terrarium for snakes should have a sand bottom and should also contain branches that may assist the snake in shedding its skin. Snakes desire warmth and concealment. The food for snakes must be alive and will have to move before they will attack it. Small frogs, tadpoles, rats, mice, lizards, and mealworms are the best foods for snakes. At times, however, snakes will eat fresh beef if it is moved about before them either on a string or held by forceps. Do not keep small snakes with large ones or you will soon have only large ones.

PRESERVING PLANT SPECIMENS.

Plants are, for the most part, easier to preserve than animals. Plant specimens which are not to be used for microscopic work may be readily preserved in a four per cent solution of formaldehyde. Very large, fleshy forms may require about a six per cent solution.

While a solution of formaldehyde is widely used to preserve plants, it has two disadvantages: a disagreeable odor and its ability to bleach the plants. The following formula is recommended because it will not destroy the green color of plants:

50% alcohol	90 cc.
40% formalin	5 cc.
Glycerine	2.5 cc.
Glacial acetic acid	2.5 cc.
Copper chloride	10 gm.
Uranium nitrate	1.5 gm.

The specimens are left in this solution until needed. About ten days are required for complete preservation. If the odor

of formaldehyde is too offensive, the specimens should be thoroughly washed in water and kept in a weak solution of ammonia, at least a day, before they are to be studied in the laboratory.

Fruits such as apples may be preserved by use of the following formula:

Distilled water	4000 cc.
Zinc chloride	200 gm.
Formalin (40%)	100 cc.
Glycerine	100 cc.

Mushrooms may be preserved in their natural colors in the following solution:

40% formalin	6 cc.
50% alcohol	100 cc.

Lichens do not require a preserving solution. Dry them, and soak them a few hours in water before they are needed for study.

HOME-MADE MODELS AND DIORAMAS

Teachers of science have been discovering that keener interest and better understanding result when pupils make or help in making models. The following techniques have been used by Mr. Fletcher J. Proctor, teacher of biology in the Concord Senior High School, Concord, New Hampshire. Mr. Proctor says, "The method used, by our pupils, in making models of a corn seed is as follows. First make a plaster of Paris block 6″ × 11″ × 1″ by mixing the plaster and pouring it into a cake tin or, even better, a pyrex cake dish for the latter gives the finished block a nice gloss. A pyrex dish also gives the worker a chance to make sure that no air bubbles form on the under side of the block for that will be the working surface. Before starting, the dish should be coated thinly with lard, Spry, or olive oil. If the finished product is to be mounted as a plaque with wooden background a means of attachment must be provided before the plaster sets hard. Ordinary paper clips that have been straightened out can be

partially imbedded in the plaster while it is still pliable. After this has been done, allow it to set for a day or two and the block will leave the dish easily when the latter is inverted. The next step is to make an enlarged cross sectional sketch of a corn seed. This should be made from an actual dissection observed under a dissecting microscope to insure accuracy. After an accurate drawing has been made, place a piece of carbon paper under it and trace the drawing on to the working surface of the plaster block. If done carefully the tracing will serve as an easy guide for the carving operation which can be completed with an old scalpel and a sharp implement such as a geometry compass. Use the latter to trace trenches where outlines are desired and ink them in with Higgins red or black ink. Trenches keep the ink from spreading. If colors are needed to make certain areas stand out ordinary water colors will do very well if water is used sparingly. Numbers for identification of parts can be made on the typewriter, cut out, and pasted on as desired. Any scratches or rough edges that remain after the carving is finished can be smoothed out with a small strip of fine sandpaper. Colorless fingernail polish will give the finished plaque a protective coating and leave a nice gloss on the finished product. Plaques and models

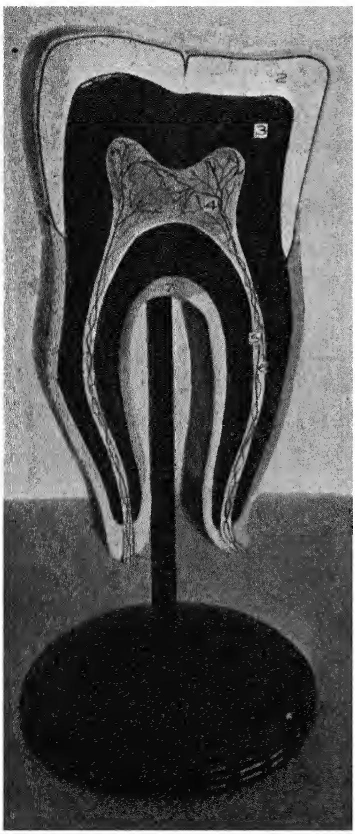

FIG. 11. A student-made model of a tooth. (Courtesy of Fletcher J. Proctor.)

have been made by the above method at costs as low as fifty cents each. Bases for the latter are easily made of wood. The important thing to remember in work of this type is that pupils must do it all or the real educational values of such projects are lost.

FIG. 12. A home-made model. (Courtesy of Fletcher J. Proctor.)

"Plaster of Paris leaf prints are also wonderful aids in a study of compound and simple leaves, veining and leaf margins, especially at times of the year when live material is not available or is difficult to obtain. Grease the pyrex dish used above and arrange a leaf on the bottom. Mix a fine batten

of plaster and pour over the leaf, being careful that none gets under the edges and that it does not move. Put the dish away for a few days until the plaster has dried out and then

FIG. 13. A diorama—A student project in biology. (Courtesy of Charles W. Gouget.)

remove the cast as described previously. Leaves usually adhere to the plaster but are easily stripped off, leaving an excellent print which will show all the required parts. To finish the plaque paint the print with colors to match the actual specimen, using a fine brush. A good leaf-green paint can be

obtained at any five-and-ten-cent store. Work of this nature is instructive and interesting, and through it we are able to stimulate some of the otherwise hard-to-reach pupils."

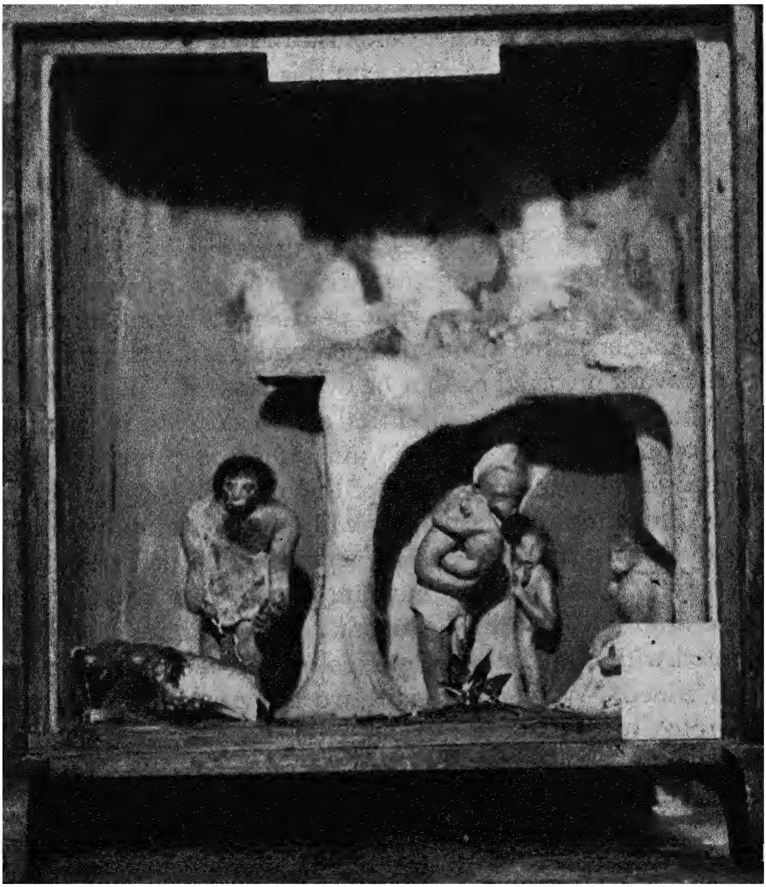

FIG. 14. A diorama—A student project in biology. (Courtesy of Charles W. Gouget.)

Many things are studied in science which cannot be brought into the classroom; for example, dinosaurs, an oil well, or a coal mine. In such cases the studying is generally done with pictures and charts. Museums have been performing a val-

uable service to science education by reproducing nearly exact images of things and processes in their natural settings. This type of model is called a *diorama*. It is one of the best visual aids yet devised because it enables pupils to visualize objects in their natural environment.

Mr. Charles W. Gouget [1] of Austin High School, Chicago, who has been experimenting with this kind of visual aid says, "A model or a diorama becomes still more instructive, and more objective and understandable, if it has been made by the student himself. Such a task requires careful observation of details to be able to complete it according to any preconceived ideas. It involves, also, the exercise of a certain amount of judgment, together with artistic and mechanical skills to turn out a worth-while product. The lasting results of learning acquired in this manner, and the training afforded by the work involved cannot be overestimated.

"The tremendous possibilities of plastic clay in producing permanent, miniature dioramas for the classroom have scarcely been touched. A few of these possibilities are shown in the illustrations. Plastic clay will not deteriorate with age, nor melt in warm weather. It can readily be torn down and built over, a fact which is most important in producing good work among high-school students. In addition it can be painted with oil paints or poster colors to which no water has been added. When the figures are properly supported, and protected by glass in a diorama case, the exhibit becomes a permanent addition to the classroom. Each new addition creates new interest and spurs group activity towards the completion of a museum as the ultimate goal in the Biology Classroom.

"It is not hard to 'sell' a subject to a student on an activity basis, if interesting objective results of previous activities can be exhibited by the teacher."

[1] Gouget, C. W., "An Objective Approach to Biology," *The American Biology Teacher*, 1:81–83, 1939.

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Chapter XIV

Designed Materials

THIS field of visual aids offers a wide variety of materials to science teachers. Designed materials, when properly employed, tend to promote a keener interest in science and a better understanding of scientific concepts by the pupils.

Certain qualities are desirable in designed materials. First, there is the quality of *simplicity*. The human mind tends to react slowly. One stimulus of intense strength is of more value than several of weaker strength. In general, one idea clearly expressed in a chart or graph gives the best results.

Second, there is a quality of *attractiveness*. Each visual aid should possess appeal. Through the proper use of colors, design, and neatness of arrangement, all designed materials may be made attractive to pupils.

Third, the proper arrangement of these visual aids enhances their value as teaching aids. A classroom in which the visual aids are poorly arranged detracts from their value. Designed materials for a particular science unit should be exhibited only during the time when study of the unit is in progress. They are not meant to be used as classroom decorations, and should be made large enough to insure perfect visibility throughout the entire classroom.

EQUIPMENT NEEDED. In order to carry out a program of designed materials the following equipment is recommended:

(1) Wrapping paper for rough or temporary use.
(2) Bristol board, 22″ × 26″, in all colors.
(3) Muslin or sign-painters cloth.
(4) Ball-pointed or spoon-bill pens.
(5) Paint brushes #5, 7, and 11, for all colors.
(6) Rubber stamps (1 inch) for letters or figures.
(7) Drawing instruments (small size).
(8) Show-card paints, crayons, and chalk of all colors.
(9) Stencils for frequently reproduced items.
(10) Costumes made by the clothing department.

(11) Stage scenery and equipment made by the manual training department.
(12) Lighting and projection equipment.

KINDS OF DESIGNED MATERIALS

Home-made and Commercial Charts. The purpose of any chart is to give a clearer meaning to the idea which it represents. Usually a chart is a flat surface upon which images have been drawn. Charts are generally accompanied by an explanation or so-called "legend." Color may or may not be used, but the proper use of colors often increases the value of the chart.

In scientific work the most common chart is that known as the "Chart of Classification." This chart gives facts in sequence thus following the scientific treatment of a subject. A chart like the one on page 108 may be made in the classroom by the students. The purpose here is to aid in the study of heredity. It may also be drawn on the blackboard or in a notebook.

In elementary or secondary science student-made charts are helpful. They help to fasten an idea or subject firmly in the mind of the child. They need not be too technical but can be composed of a collection of pictures or drawings of objects seen on the school journey or in the classroom. The child should label each drawing or object on the composite chart.

Home-made and Commercial Posters. The poster, as a visual aid, is widely used and is very effective. Like the chart, the poster expresses the main thought or idea. Here too, the use of color and designs helps to build up the appeal.

Students should be encouraged to make posters. The fields for the subject are many. Some of these are: astronomy, agriculture, animals, biology, clothing, chemistry, communication, diets, foods, health, industrial processes, radio, and safety. The poster is of value where the project method of teaching is used. The poster also provides an endless source of interest for those pupils with ability and interest in drawing.

It is generally desirable for the teacher to give some instruction to the pupils in cutting out pictures, drawing lines, and using color to advantage. No particular training is needed in art or design.

Even the blackboard may become a poster, as it usually does during Christmas festivities at school. At this time the blackboards are usually resplendent with various drawings of Saint Nicholas and his reindeer. Red and green colors are used for effectiveness.

Lately the poster has been employed as a subtle means of spreading propaganda. Commercial companies use this type of visual aid by having advertisements on billboards, car cards, newspapers, wrapping paper, and magazines.

Graphs. A graph is a drawing which represents a fact or a group of facts or an idea. A graph is a chart form of presenting statistics.

Graphs are useful to the teacher in several ways:

(1) They help the teacher in focusing the attention of the pupil in the direction desired.
(2) They make it easier for the pupils to grasp the meaning of statistical data.
(3) They help to clarify thinking with reference to facts.
(4) They help to arouse interest in statistical data.

If graphic materials are integrated with other visual aids they will increase the effectiveness of the science unit. An examination of Unit 10 in Heiss,[1] Obourn, and Manzer's *Our World of Living Things*, will reveal how graphs have been used to develop a unit of study in high-school biology.

The blackboard and the bulletin board may be used as media for the display of graphic materials. The following suggestions are offered as a means of making the blackboard a more efficient device for the visualization of scientific data and concepts:

(1) Graphs whether made by teachers or pupils should be an expression of their best efforts.

[1] Published by the Webster Publishing Co., St. Louis, Mo.

(2) Too many graphs or charts on the blackboard at one time may divide attention. It is recommended that only one or several be exposed to the students' attention at one time.
(3) Graphs should be definitely related to the topic under study or discussion.
(4) Drawings on the blackboard should be clearly visible to all the students in the room.

When constructing a graph the student should work from left to right on the material used. A "legend" or "explanation" should accompany the graph and be plainly legible. Whenever possible the writing of this explanation and also the labeling of the graph should be written horizontally. It is best to outline the graph in pencil first and then carefully use ink. Care is required here, as careless inking of a graph may destroy its scientific accuracy.

KINDS OF GRAPHS.

Bar Graph. These graphs have either a line of varying width or bar to indicate the facts. A row of bars or series of columns may represent a series of closely connected facts.

Vertical Bar Graph. The vertical bar graph is constructed with the bars placed on the horizontal or base line. The value of each bar is determined from a vertical scale.

Horizontal Bar Graph. In a horizontal bar graph the bars are placed on a vertical or base line. The value of the bars is determined from a horizontal scale. Horizontal bars are preferable to vertical bars. The eye can compare horizontal distances more easily than vertical distances.

Component Bar Graphs. Sometimes in bar graphs the bars are divided into component parts to show related facts. Since the bar is the whole, it is divided into as many parts as desired, depending on how many components are to be represented. Each component is represented differently from the other by various devices such as shading, cross-hatching, filling-in with colors, or heavy outlining.

Component bar graphs may be made to scale or not to scale. If they are not made to scale, the values are usually marked on the bars. With a scale, this marking is not necessary.

Circle Representations. Circle graphs are used to show percentage or fractional values of a whole. To make circle graphs accurately requires the use of a compass and a protractor for measuring degrees and laying off angles. The following general rules in teaching pupils how to make circle graphs will be helpful:

(1) Make sectored circle graphs in preference to concentric circles. Concentric circles are difficult to compare.
(2) Print all titles neatly at the top of the graph.
(3) Whenever possible print labels within the circle in a horizontal line.

Sectored-Circle Graph. In making a sectored-circle graph the percentage values are reduced to degrees, and the space measured with the aid of a protractor. One per cent of value is represented by an arc of 3.6 degrees. Twenty-five per cent of value is measured by an arc of 90 degrees. Since the eye cannot estimate accurately the percentage value or fraction of the whole for each sector, it is advisable to label each sector with its percentage value. Shading or coloring the sectors, or the use of dots or cross-hatching will aid in differentiating the sectors and make the graph more attractive.

Curve Graph. Williams [1] defines a curve as a line connecting a series of points whose relative positions indicate comparative values. The curve graph is widely used in the scientific and industrial world to show trends of facts and variability. Every science teacher should understand how to plot curves and how to read them. The following general rules should prove helpful in constructing curve graphs:

(1) The zero line of the scale for a curve should be heavy and sharply distinguished from the other coördinate lines.
(2) It is advisable not to show any more coördinate lines than are necessary to guide the eye in reading the diagram.
(3) The curve lines of a diagram should be sharply distinguished from the ruling.
(4) The horizontal scale should read from left to right and the vertical scale from bottom to top.

[1] Williams, J. Harold, *Graphic Methods in Education*, Houghton Mifflin Co., 1924.

(5) Figures for the scale should be placed along the respective axes.
(6) The title of the diagram should be made clear and as complete as possible. Subtitles or descriptions should be added if necessary to insure clearness.
(7) In plotting curves, neatness and accuracy should always be striven for. A hard-edged ruler and a sharp pencil are necessary for accurate work.

The curve graph, when carefully made, is highly accurate. It is less attractive, however, than some other kinds of graphs. It is preferred by scientists, and statisticians whose reports are mainly for technical use and for whom attractiveness is of minor importance.

AREA GRAPHS. Any geometrical figure which will show comparisons by size differences may be used to express simple areas. The most common figures for graphic representation of this kind are: squares, triangles, rectangles, and circles.

PICTURE GRAPHS. Picture graphs are charts in which quantities are represented by means of pictorial symbols. The symbol used is always a likeness of the thing which it represents. Wherever data lend themselves to symbolic representation it is recommended that they be graphed in pictorial form. Picture graphs tend to animate statistics and make data concrete and interesting which would be otherwise dull and abstract.

The following rules should be considered before making picture graphs:

(1) Symbols should be self-explanatory.
(2) Larger values are shown by a larger quantity of symbols and not by larger symbols.
(3) Graphs compare approximate quantities—not minute details.
(4) Only comparisons should be graphed—not isolated statements.

The pictorial symbols used in picture graphs should be selected with special reference to the laws of association: data pertaining to war might be represented by guns or battleships or soldiers. Data pertaining to peace might be represented

by the dove as a symbol. The student thus associates the symbol with a certain topic.

Color is also symbolic and associated with various objects. For example:

Red.....fire, blood, war, Indians.
Blue.....sky, water.
Brown...ground, wood.
Black....death, dejection.

THE LADDER PICTURE GRAPH. This graph naturally suggests a rise to a higher plane, such as a rise in fame, education, or prices. A ladder is used as the symbol.

THE THERMOMETER PICTURE GRAPH. This form of graph is also suggestive of a rise in value or height. It may be used to represent temperature rise, water rise, etc.

THE DIAGRAM.

The diagram is essentially a blue print of a process depicting some continuity, order, development, or procedure. In the diagram, facts or ideas are reduced to skeletal forms. No matter what is portrayed in the diagram, the basic interrelationship of facts is ever present. In this sense, the diagram is the most abstract of visual aids.

Certain factors may operate to make the diagram effective and meaningful. Previous discussion in the classroom will add interest. The school journey will supply some basis for detailed study. This may be such a topic as an industrial process or architectural planning of a house. Whenever the diagram is used it should be used as a follow-up technique.

The application of the diagram as a visual aid in science teaching is apparent. Certain scientific laws and concepts lend themselves easily to this method of illustration. The laws of falling bodies, the laws of motion, and the laws of heredity may all be illustrated by the diagram. Such concreteness of illustration as the step-by-step development in the diagram is an important advantage.

No special technique is needed in making a diagram. If

the blackboard or notebook is used, the diagram can be outlined lightly at first and then drawn in bold relief later. The pupil will often do this, particularly if developing the diagram step by step in class. Then too, colors may be added to suit the requirements and, if used, will aid in the effectiveness.

The effectiveness of the diagram will depend on its visibility. Unless the lettering, numerals, or other means of identification are plainly visible, they will be of little use. Elimination of nonessentials, prevention of crowding, and strong drawing will assist in the readability of the diagram.

THE CARTOON.

The cartoon is an illustration dramatizing or emphasizing a fact (or facts) by means of satire, humor, fantasy, or incongruity. The cartoon is a very popular form of visual aid. When properly used, the cartoon is very effective in teaching certain phases of science.

The cartoon has universal appeal. Several ways of strengthening and increasing this appeal are as follows:

(1) Avoid technicalities by simplifying the facts or ideas of the cartoon. This will stimulate the imagination of the pupil and create additional interest.
(2) Associate the facts in the cartoon with experiences common to the pupil's daily life.
(3) Supply enough explanation or "dialogue," if necessary, to make the cartoon understandable.
(4) Make the drawing of the cartoon strong and bold for visual effectiveness. Weak lines in a drawing have little or no appeal.
(5) Select the proper symbols for the cartoon. The symbol chosen should be suggestive of the fact to be portrayed. For example: the dove portrays peace: the book portrays education or learning.
(6) Whenever possible, apply the proper use of colors to the cartoon. Even colors are symbolic. Use the complementary colors if contrast is desired; that is red and green, blue and yellow, black and white.

The cartoon is not a blue print. Technicality of drawing is not the factor to be gained. The cartoon often has more

effect if freehand drawing is used. Each pupil can then make and design the cartoon, or cartoons, with the teacher as a guiding factor. The entertainment appeal will be much greater if the students are allowed this freedom.

The cartoon is being applied daily to the sciences. The study of health is being fostered by countless advertisements in cartoon or comic strip form. In the motion pictures the association of "Popeye" with a diet of spinach is quite apparent.

MAPS AND GLOBES.

Maps and globes have long been associated with the teaching of history and geography, but a proper place should also be given them in the field of science. These visual aids are necessary for successful teaching of such special science fields as physiography, topography, meteorology, and geology.

The purpose of a map or a globe is to present concretely features of the earth such as natural boundaries, topography, regions of water, ice, and land. The map or globe may present other conditions as follows:

(1) Climatic conditions—weather, arid and fertile areas, wind velocity, temperature.
(2) Time considerations—the Analemma, time dial, time belts. There are various kinds of maps and globes.

a. Relief Maps and Globes. These visual aids give concrete impressions of surface conditions. They show elevations and depressions. Such a map or globe can be made by the student. Usually plastic material (paper, pulp, plaster, or soap) is spread on cardboard. Indentations are made in the soft material and then allowed to harden. Relief maps and globes are not highly accurate because of the tremendous size of the earth in comparison to the map or globe. Nevertheless pupils do gain a more nearly correct impression of surface conditions of the earth from these visual aids than is possible without them.

b. Physical Maps and Globes. These visual aids give information about the physical characteristics of geographical regions. They are of three types:

(1) *Graphic relief* indicates elevations of land above sea level by light and dark shades. Shows natural topography and roughness.

(2) *Contour layer* intervals between the contours are colored or shaded: generally blue for ocean, green for lowlands, and red and yellow for highlands.

(3) *Natural region* made to show natural regions. The regions follow the most important surface relief features of the earth. By means of a special color scheme these maps give a clear picture of the distribution of mountains, plateaus, plains, and uplands over geographic areas.

c. WEATHER MAPS. Weather maps show climatic and weather conditions of a region. Conditions of temperature, rainfall, wind velocity and air pressure are shown. The symbols which are used to represent the physical quantities are given on the map.

d. ECONOMIC MAPS. An economic map shows the products of a region.

DRAMATIZATION

In formulating plans for the use of a dramatic aid in science teaching the selection of a proper vehicle of dramatization is important. The following methods of dramatization may be considered:

1. *The Play.* This is generally a stage performance where lines are spoken by the players during the act.

2. *The Pageant.* In this form of dramatic aid a procession of historical scenes with the characters in costume is portrayed.

3. *The Pantomime.* This is a play in which there is merely acting. No words are spoken during the action.

4. *The Tableau.* The tableau is a picture-like scene represented by one or more silent and motionless persons in proper attitude and costume, often with suitable accessories.

5. *The Puppet Show.* The puppet show is a small scale stage on which miniature figures (marionettes) are moved by means of strings or wires to each position desired. This is a popular form of dramatic aid. The puppet show requires a great deal of preparation but it is generally very effective. Students in

the art department can make the puppets and conduct the show. The puppet show is generally used in the elementary school but is just as effective in the secondary school.

The proper selection of the cast of characters is necessary. A good story or plot may be literally ruined by a poor cast of characters. The teacher should select the right student for each part to be played. It is best to have one or two alternates for each part in the dramatic aid. A double cast will secure more interest, will present wider values, and will provide experience for future dramatic presentations.

The properties and settings can be obtained through the coöperation of the faculty. Other departments may assist and the students will value the dramatic aid more if they are allowed to assist in the actual construction work. Much knowledge can be gained by the student when assisting in this way.

Finally the rehearsal will be complete as a unit if the other departments assist. The dances are often supervised by the physical education department. The costumes may be made by the home economics department. Stage settings are usually handled by the manual training department. If historical scenes are to be presented, the history department may assist. Lighting and projection apparatus can be directed by the science department. Songs may be supervised by the music teacher. Tickets and seating may be handled by the mathematics department. If the various departments will coöperate, a better dramatization may be produced.

EXAMPLE OF A DRAMATIC AID.

An example of the use of dramatic aids in science is given in a program presented at Palmyra High School, Palmyra, N. J., during an assembly period of the school year 1936–37 as follows:

SCIENCE PROGRAM

THE ADVANCEMENT OF MEDICAL SCIENCES THROUGH THE AGES

Part I. Primitive Practices in Medicine
Sketch: The Medicine Doctor as shown by the Indians.

Part II. The Transitional Period
Tableau: Dining Scene in Ancient Castle showing unsanitary conditions of the time.
Part III. A New World Is Discovered
Play: Scenes from the life of Pasteur
Part IV. Modern Medicine
Tableau: The Nurse (Florence Nightingale) and Doctor at work.

The program took forty-five minutes, allowing a few minutes for the change of stage equipment between the parts. Each teacher in the science department supervised one of the four parts, both directing and equipping the students. Students assisted in the costume making, which did not entail much expense.

The following is an example of the use of puppetry in science and is a puppet play written by one of the authors and presented as an Arbor Day Program in the auditorium of a high school in New Jersey:

A LESSON IN FOREST CONSERVATION

1. *Scenes:*
   - Scene #1: Natural forest background painting by a student. Dirt and sod on stage.
   - Scene #2: Same as #1 with addition of a campfire (lighted) and subdued lighting for night scene. Tent shown.
   - Scene #3: Background changed to show a forest destroyed by fire, charred trees, etc. Burned material on stage. Odor of burning wood.
   - Scene #4: Use #1 background again, and tent, with campfire extinguished. Increased lighting. Early morning.
2. *Cast of Characters:*
   - Puppet #1 (P–1), known as Bill (a doctor)
   - Puppet #2 (P–2), known as Jim (a business man)
   - Puppet #3 (P–3), known as Harry (a lawyer)
   - Puppet #4 (G. W.), known as Game Warden
3. *Costumes:*
   Puppets Nos. 1, 2, and 3 were dressed in green Robin Hood type suits. Game Warden dressed in brown uniform.

Scene #1

Curtain opens on natural forest scene, with no puppets on the stage. P–1, Bill, comes on the stage, points to the forest and recites—

P–1, Bill. "This is the forest primeval. The murmuring pines and the hemlocks
Bearded with moss, and in garments green, indistinct in the twilight,
Stand like Druids of eld . . ."

[Enter P–2, Jim, as P–1 sits down. Imitation of sounds of birds.]

P–2, Jim. Where shall I place our camping equipment, Bill? You sure have picked a nice cool spot for us to camp on during the week.

P–1, Bill. Yes, that is the beauty of the forest. One can come here for solitude, for rest, and for peace of mind. A bit of heaven, as one might say, placed here by nature for us to enjoy.

P–2, Jim. That's right, Bill. I have been looking forward to this camping trip all week so that I, too, might have a chance to get away from the cares of the business world. A visit to the woods sure peps up a person. I expect to go home a new man, full of zest and vigor from the experiences gained here.

P–1, Bill. Well, Jim, I'm glad you feel that way, because we are here to rest, fish, hunt, and enjoy nature. It's getting late—suppose we start to unpack our tent? By the way, is Harry bringing the food?

[They start to unpack. Harry, P–3, comes in with packages under one arm and wooden gun under the other.]

P–3, Harry. Well, fellows, here's the food. Looks like you fellows are starting to enjoy the woods by pitching the tent. I think I'll stroll around a while and see if I can sight some wild animals.

P–1, P–2 (*in unison*). O. K., Harry.

P–2, Jim. Don't be too long—supper will soon be ready. We will call you, so don't go too far.

[Harry, P–3, goes sauntering off stage. Curtain closes.]

Scene #2

The tent is set up on the stage, campfire built and lighted. P–2, Jim, is holding pan over fire. P–1, Bill, stands near tent. Subdued lighting.

P–2, Jim. Bill, give Harry a call. The grub is ready.

[P–1, Bill goes to side stage and calls.]

P–1, Bill. Harry! Harry! Supper is ready.

[He listens and P–3, HARRY, calls faintly (off stage).]

P–3, HARRY. I'm coming, boys!

[P–1, BILL, walks over to the lighted campfire and sits down.]

P–2, JIM. Boy, the food smells good! Being out in this atmosphere sure gives one an appetite!

P–1, BILL. I think so, too. One can come to the woods and work up an appetite for some real food. While at home my appetite isn't as real as the one I get out here. This cooking with nature's implements gives a camper a real thrill.

P–3, HARRY (*entering, goes towards them*). Say, fellows, this is a very pretty spot (*sits*). I'll tell you all about my short walk as soon as I satisfy my hunger for some of that crisp bacon and coffee.

[All three pretend to eat food. If possible rattle some tableware, such as forks and knives, or scrape an aluminum pan.]

P–1, BILL. Let's sing something, boys.

[P–3, HARRY, starts backstage, with guitar, mandolin, or mouth organ]

P–3, HARRY and rest. "Oh give me a home,
Where the buffalo roam,
Where the deer and the antelope play—"
(full song).

P–2, JIM. That's fine, fellows. Look up at those tall trees, like giants, towering against a background of silver. Somehow I feel as though there is more to life than sitting at a desk giving orders. Just think how nature is giving us orders to enjoy her beauty, her freedom, her spirit!

P–1, BILL. Yes, you are a successful business man at home, but nature does not ask us who we are. Look at me, a doctor, busy every day in the office, treating patients with all sorts of ills, dabbing antiseptics here and there and trying to relieve mankind of its numerous ailments. Then to the hospital late at night, while all are asleep, and operating amid ether fumes and other anesthetics. Then home in the early morning hours to rest—not a deep sleep of the peaceful kind, but that of restlessness after hard labor. And here I sit, far from the ills and pains of the world, enjoying myself, breathing in the purified air and opening my soul to nature's wonders. What a heritage can be found in the woods! Oh, if we only would appreciate them more.

P–3, HARRY. And I, too, a lawyer—standing in the court each week, arguing and pitting my brain against the most skillful of my

profession; delving into some old musty law book for this or that ancient law and all the time forgetting that nature's laws are far greater than any of man's substitutes. You are right, Bill, nature doesn't ask us who we are but *what* we are.

P–1, BILL. I think so, too. Well fellows, I'm getting tired. Guess I'll turn in. Are you fellows sleepy, too?

P–2, P–3 (*in unison*). You bet.

[They turn in. After a few minutes there is heard some slight snoring. The campfire spreads out and sets fire to the trees. This is done by pulling the red light toward the back of the stage, and throwing red lights on the scenery. P–1, BILL, appears to wake up and sees the fire.]

P–1, BILL (*yelling*). Forest fire, boys. Let's go get help! (*They yell for help.*)

[The puppets move hurriedly off stage and the curtain is drawn.]

SCENE #3

This scene shows a destroyed forest in the background. Trees are charred and black. White light is thrown on stage. The three puppets come sauntering in.

P–1, BILL. Well, fellows, here's our old camping site. Just look at it now—no longer a beautiful place to camp. No shelter, no foliage, no singing birds. Can it be possible that a single match could cause so much trouble?

P–2, JIM. Yes, Bill, it is possible. If we had been more careful we would have put out the campfire before it had a chance to spread and caused so much damage. It was pure carelessness on our part and we are to blame. Here we were, enjoying ourselves to the fullest but not taking care of what we had. Now we do not have it to enjoy.

P–3, HARRY. Well, I feel that way, too, fellows. We are all guilty of a crime far greater than we can realize. No longer will we be able to come here and enjoy what we had.

[The GAME WARDEN enters from the side of the stage.]

G. W., GAME WARDEN. Sorry, boys, but I must arrest you in the name of the law for causing this forest fire. All of you know that the penalty is ten years in jail at hard labor.

[GAME WARDEN starts to lead them off stage. As they go off, P–2, JIM, goes last, but fights the GAME WARDEN all the way off the stage. Curtain closes.]

Scene #4

Return to original scene #1, natural forest scene. Bright light on stage. Puppets are still sleeping on stage near campfire. P–2, Jim, is in a half sitting position, waving his arms wildly in the air, and yelling:

P–2, Jim. Let me go, Warden. I didn't mean to do it, honest—honest, I didn't mean to do it . . .(*loud*).

[All the puppets sit up quickly as if startled.]

P–1, P–3, Harry and Bill. What's the matter, Jim! Speak, man, speak!

P–2, Jim. Oh boys, I had the most terrible dream of all. I dreamt that we carelessly left the campfire burning last night and it set fire to these beautiful woods and destroyed them. Then the game warden came along and arrested us for causing the forest fire. Gee, it was awful! This place certainly looked a mess.

P–3, Harry. Well, Jim, I guess you did have a bad dream and it would have been terrible if it had actually been true. Your dream has taught me a good lesson.

P–1, Bill. Me, too, Jim!

P–3, Harry. I guess we never value what we have until we lose it. Tell you what, boys—when I go home to my law office, I'm going to instruct all my members of the law firm in the principles of forest protection. And I'm going to line up with the state in its drive against such carelessness and the apprehension of such criminals. Believe me, they'll be prosecuted too!

P–1, Bill. You can count on me too, Harry. The forest fire is one ill that I, as a doctor, cannot cure. I know what it means to human beings when they get burned by fire and so I can imagine the loss we suffer through such carelessness. I'm going to tell my patients who need a rest to come here and I personally will instruct them in the methods of forest fire prevention.

P–2, Jim. Hey—don't leave me out of this, for I, too, have learned a lesson. And you may be sure my business associates will be trained that way also. It's daylight now, so let's get up and enjoy the beauties of these woods before we leave.

[The puppets arise and stroll off stage. They point to the natural forest background. The curtain is drawn.]

Finis

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Send 3¢ stamp to cover postage.

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"Dream Gardens"
"Picnic Ways on Picnic Days"
"The Garden Patrol"
"The Broken Ring"
Write for list of others.

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Chapter XV

The Microscope[1]

THE microscope is one of the important tools of the scientist. By means of the microscope subvisual objects are made visual by magnification with lenses which concentrate rays of light in the receptive portion of the eye.

Not only is the microscope an important tool but it is a delicate and expensive one as well. It requires careful handling and skillful manipulation. Information pertaining to the care, use, and construction of the microscope is presented in this chapter together with suggestions on how to prepare microscope slides.

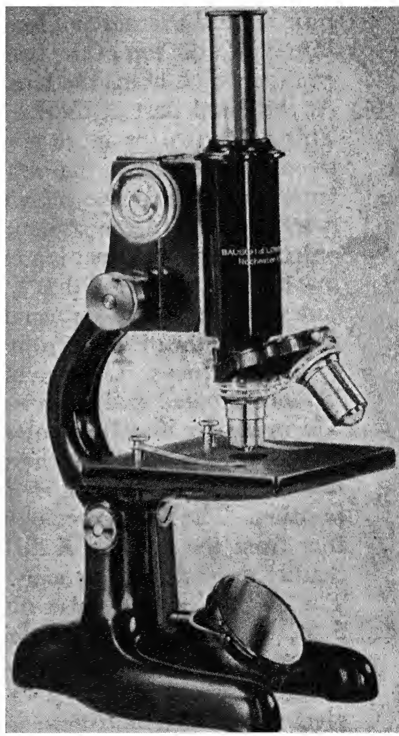

FIG. 15. A compound microscope. (Bausch and Lomb Optical Co.)

CARE OF THE MICROSCOPE.

(1) In removing the microscope from the case, grasp the instrument by the curved frame. Carry it in an *upright* position and do not let it strike any hard object.

(2) Make any adjustment of the parts slowly, holding the frame while the parts are being moved, except when focusing.

[1] The authors are indebted to Professor James Meyers and Professor Malcolm E. Little, both of New York University, for their permission to use the materials on the microscope from their laboratory outlines in college biology.

(3) Do not use any rough or dusty paper or cloth on any parts of the instrument. Always use lens paper in cleaning the lenses.

(4) In replacing the instrument in the case, carry as before; and be certain that the bottom lenses (*the objectives*) are turned so that neither is pointed directly downward.

STRUCTURE OF THE MICROSCOPE.

(1) The iron framework is divided arbitrarily into the *arm*, the upright portion, and the *base*, the portion upon which it rests.

(2) The upright, tubular structure is known as the *body tube*. This tube holds the lenses and is an essential part of the instrument.

(3) Fitted into the top of the body tube is the removable *ocular*, or *eyepiece*, which holds the lens nearest to the eye.

(4) At the basal part of the body tube is the revolving *nosepiece*. This holds two or more removable small tubes which hold the lenses nearest to the objects. These tubes (including the lenses) are called the *objectives*. The objectives are two (or more) types. In the student's microscope one is a *low-power* objective, and the other is a *high-power*. The low-power usually magnifies ten times (10 ×), and the high-power forty-three times (43 ×). This is usually marked on the objective, together with the distance from the object at which the objective comes into focus. Objectives with higher magnification used in more detailed studies are usually known as "oil immersion." The nosepiece may be revolved so that either objective points directly at the object on the slide. The correct position is indicated by a slight click as the objective reaches the correct position. The low-power objective is shorter and focuses farther from the object. A little practice and observation will readily show the difference.

The *oculars* (*eyepieces*) also differ in magnifying power either 5 ×, 10 ×, or 15 ×. To determine the magnification of an object under the microscope *multiply* objective number by the ocular number. That is, a 45 × objective with a 10 × ocular gives 450 × magnification.

(5) Below the nosepiece is the horizontal stage. This is attached to the arm, and is usually movable (but it is not to be disturbed by the student). The object to be studied is placed on the stage, directly under the objective. Such objects should always be placed on a clear glass slide. The opening in the stage, through which the light is reflected, indicates the proper position for the object.

(6) The space below the stage is called the substage area. In this region several structures may be found.

(a) The *condenser* is a lens which helps in focusing the rays of light on the object. This may be moved up or down with the turn of the screw on the student's left when the microscope is in position with the arm of the microscope toward the student's body.

(b) The *diaphragm* is attached to the movable condenser. This opens and closes and admits or shuts out light as it enters the condenser. Most students prefer to control the amount of light with the condenser rather than the diaphragm. The diaphragm is controlled by the small lever toward the front of the condenser.

(c) The *mirror* is one of the most important parts of a microscope. Proper light is *usually as important* as proper magnification. The mirror has two faces, one flat for use with strong light; the other concave for use with dimmer light. Most errors in microscope use come from a lack of understanding of *lighting*. Microscope studies are made with light reflected from the mirror. Recall that the light rays leave a mirror at the same angle at which they strike the mirror (*i.e.*, the angle of incidence equals the angle of reflection). The mirror may be rotated in two directions. *Keep Experimenting* with the mirror until you can understand the principle and practice of the reflection of light in a microscope.

(7) Focus adjustment. On the upper part of the frame will be found two adjustment screws which raise and lower the body tube. The larger is called the "coarse adjustment" and will raise and lower the body tube a relatively large distance by a single revolution. The smaller or "fine adjustment" moves the body tube an almost imperceptible distance. In focusing an object the fine adjustment is used to complete the process by bringing the object into more delicate focus. In this way the latter is used to supplement the coarse adjustment screw and thus to bring out the finer details of structure.

USE OF THE MICROSCOPE.

(1) In securing the microscope lift the instrument by the arm and then balance with the base in the palm of the other hand. Never tilt the microscope.

(2) Place upon the desk with the arm toward the edge of the desk and do not tilt the stage.

(3) Turn the nosepiece until the low-power objective is in line with the body tube and ocular.

(4) By means of the mirror focus the light rays up from the concave surface through the condenser. By placing the eye at the ocular you should be able to see the light field, if the objective is in alignment.

(5) NOTE carefully if there are any defects or dirt marks on any of the lenses. If so determine where they are located.

(a) Revolve the ocular while looking through same. If the mark moves then it is located in this part.

(b) Change from low to high-power objective. If the dirt disappears then the low-power objective needs cleaning.

(c) If there is a slide under the microscope, focus it and then move it from side to side. If the mark moves then the slide should be cleaned.

(d) If none of these methods locate the speck then clean condenser and mirror.

In cleaning all of the lenses always be sure to use lens paper. *Always wipe the slide before using.*

(6) Place the slide under the objective with the material to be studied directly over the hole in the stage. Focus the light up through the stage. Turn down the low-power objective as close to the slide as possible without touching it. Then with the coarse adjustment turn the body tube slowly upward until the slide is in focus. In focusing it is often advisable to move the slide gently while raising the objective. When the slide is in focus it will be noticed that the slightest defects in the glass are noticeable. This will serve as a guide since at first it is difficult to place material to be studied directly in the field of vision. After it has been located in the center of the low-power field then the high-power objective may be revolved into place. When this has been done it will be advisable to increase the amount of light since higher magnification requires more light. This adjustment may be made by opening the diaphragm, or raising the condenser, or by a combination of both. Then proceed as with the low-power, first lowering the objective as near the slide as possible and then raising it. *Never focus downward.*

(7) In using the microscope it will be advisable to keep both eyes open and thus to relieve unnecessary strain. This will be difficult at first, but by practice may be formed into a habit.

CAUTIONS.

Keep both eyes open.

When carrying a microscope do so by balancing the base on one hand and holding the arm with the other.

Clean lenses with lens paper only.

Do not attempt to take the microscope apart.

Always focus upward.

Always focus with the low-power first and then with the high.

The efficiency of the microscope is dependent upon the efficiency of the user.

The light must be carefully regulated in order that the object may be seen clearly.

PREPARATION OF MICROSCOPE SLIDES

As stated in the exercise of the microscope, any object to be studied under the microscope is mounted on a glass slide. Many of these slides are permanent preparations or "prepared slides"; while others are made in the laboratory for immediate use and are temporary in nature. The latter are usually known as "wet mounts."

MAKING A PERMANENT MOUNT.

The technique of making permanent preparations is usually complicated, and is not a part of the biology laboratory work. The student, however, should understand the nature of these mounts.

(1) A permanent preparation involves covering the object with a very thin glass "cover slip" which protects the object from loss and crushing.

(2) The cover slip must be firmly attached to the slide with a transparent material. For this purpose a resin, Canada balsam, is used. This substance is soluble in xylene (one of the benzene group of hydrocarbons) and can be made to any consistency. In addition to transparency, the resin has approximately the same refractile index as the glass slide, and causes little distortion of the light rays as they pass through.

(3) Any *dry* small object is mounted by:
   (a) Placing the small object on a glass slide;
   (b) Covering with fairly thin balsam (in solution); and
   (c) Carefully placing a cover slip on the top. Care in placing the cover slip is *always necessary* to prevent air bubbles from forming under the slip. Air causes a great distortion of the light rays, and destroys the value of the slide.

(4) Most biological specimens used for study are not dry, for protoplasm is a colloidal suspension. Water and xylene are

not miscible, therefore, the object must be dehydrated. This is done as follows:

(a) The protoplasm is killed with strong poisons to prevent distortion of the object.
(b) The water is removed with alcohol—the object being carried through a progressive series of alcohol until they are in almost pure grain alcohol ("absolute alcohol" which is purer than the 95% alcohol).
(c) As pure alcohol and xylene are miscible, the object is then immersed in xylene to remove the alcohol, and then placed on the slide and mounted.

PREPARATION OF SECTIONS FOR STUDY.

Biological materials are frequently too large for mounting on a slide. In this case the specimen or a fragment of it must be sectioned, or cut into thin slices. These slices must be sufficiently thin to be transparent. To cut the materials thin it is necessary to have the materials firm and yet soft enough for the knife to cut smoothly. Several substances are used for this purpose, but paraffin is the most widely used.

Before the sectioning begins, every cell of the organism or fragment must be thoroughly filled with the paraffin. The process is briefly as follows:

(1) The fragment (tissue or organ) is "killed." The cells are then said to be "fixed."
(2) After killing, the fragment is carried through the alcohols for dehydration. After removing the water, the cells are then placed in xylene, as in making total mounts of small objects.
(3) Xylene is a solvent not only of resin, but of paraffin. Therefore, the tissue is placed in a vial or dish of xylene, and melted paraffin is added. From this mixture the specimen is placed in more paraffin until all the xylene is removed.
(4) After the melted paraffin penetrates all the cells of the tissue, the cells are said to be "completely infiltrated." It should be understood that paraffin of a fairly low melting point is used, so that the tissue will not be baked in the process.
(5) The tissue is now embodied in a block of paraffin and can be cut. The simplest cutting device is a heavy sharp knife. This is "freehand" sectioning, and is quite accurate in the hands of experts.
(6) For very thin sections, and for perfect accuracy in getting the

slices the same thickness, an instrument called a *microtome* is used. This instrument is so geared that it is possible to cut out sections 1/25,000 part of an inch in thickness. The average laboratory slide material is cut about 1/2,500 part of an inch in thickness.

PREPARATION OF WET MOUNTS.

In biological work much of the material is living, and must be handled carefully. The living organism or cells *must be kept* moist. For fresh water organisms, with cells which need not be kept alive for more than a few minutes, tap water is used. For cells which are taken from larger plants and animals, the fluid which is placed around them must be similar to the body fluids of the organism. Otherwise, the cells rapidly degenerate. The fluids which are in balance with the body fluids are called "physiological solutions," and such solutions are made by adding various salts to the water. If nutrient substances are added also, the cells may be kept alive indefinitely (provided temperature and acid concentration are kept constant and suitable to the cells).

In the preparation of a wet mount always keep in mind that the use of the microscope is dependent upon the passage of light rays through the material on the slide. If the object is too dense, the light will not pass through and the details will not be visible. In some cases this may be remedied by letting the light fall directly on the surface of the object (that is, not reflected from the mirror). One thus sees the object with the light directly reflected from the surface. This method is worthless except for surface study.

Before making a mount, make sure that all the glassware, including the slides, cover slips, pipettes, and other apparatus are *clean.* If not, the visibility will be lowered; and if any chemicals are on the apparatus, the specimen may be killed.

CAUTIONS.

(1) Always use a cover slip when using a compound microscope.
(2) Always focus first with the low-power, and then turn to high. Use the fine adjustment, first turning the screw counterclockwise. (This brings the objective away from the slide.) If the

object does not come into focus, lower the fine adjustment *slowly* over the object. *Make sure that the objective is neither dirty nor wet. Do not* let the objective hit the slide, or the objective may be scratched.

(3) Remember that a microscope can be focused at infinitely minute distances. In other words, a section of tissue only 1/25,000 of an inch in thickness is not seen all at once under the high-power. You can focus at the upper surface of the section, in the middle regions, or at the lower surface.

(4) In thin sections most of the cells of the tissue will have been cut, so that all the cellular structures will be present in relatively few of the visible cells. In this case a composite picture may be made by studying adjoining cells.

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Chapter XVI

The Telescope[1]

ASTRONOMY has been one of the neglected areas of science. It is hard to understand why this is so. There is a variety of evidence which indicates that both children and adults are keenly interested in heavenly bodies. It cannot be argued very well that the study of astronomy is not needed in our scheme of public-school education when the primary aim of science teaching is to give the people an understanding of objects, forces, and phenomena which make up their surroundings.

Sometimes astronomy is neglected because of erroneous notions concerning the expense involved or lack of information concerning what may be done with a small instrument.

Expense is no reason for excluding the study of astronomy. The telescope is the only instrument needed, and it does not wear out. The cost of such an instrument is usually much less than the cost of equipment for teaching any other laboratory course. No housing or observatory is absolutely necessary. It should be remembered that an observatory is primarily a shelter for a permanently fixed instrument and hence is unnecessary if a portable model is used.

In considering expense, the question of whether the instrument should be a reflector or a refractor is sure to arise, as it is ordinarily possible to purchase a larger reflecting telescope for the same amount of money as a refracting telescope. There are, however, several advantages which have caused the refractor to remain the most popular type for educational situations, while the small-sized reflector remains preëminently the instrument of the amateur astronomer. The care required by the mirror, which must be resilvered at reg-

[1] The authors are indebted to the Bausch and Lomb Optical Co. for their kind permission to use materials liberally from their publication, *Teaching with the Telescope* by E. S. Bissell.

ular intervals, the awkward shape of the instrument and generally unattractive appearance, together with its optical limitations, has never enabled the reflector to gain favor in the educational field. The refractor on the other hand is easily portable in sizes having objectives as large as 4 inches.

Such an instrument presents an attractive appearance, requires nothing but ordinary care and treatment, and represents a permanent investment. It is possible to obtain such instruments in the standard sizes of 60 mm., 80 mm., and 102 mm. objectives. Telescopes of the latter size are considered large enough to warrant the equatorial mounting and can be had equipped with a permanent base, clockwork, hour circles, and all other necessary equipment. Such a telescope makes a fine observatory instrument for the small college or large city high school, at the modest price of about one thousand dollars. On the other hand it is possible to do good work with the small 60 mm. instrument.

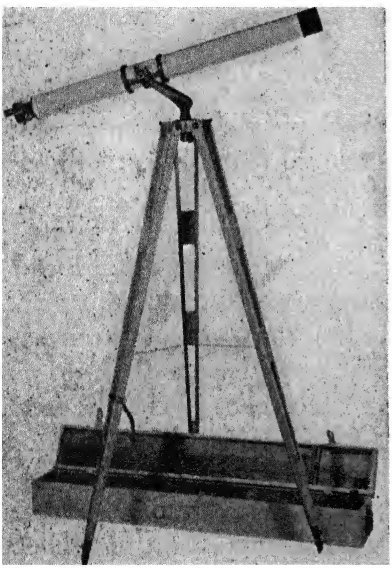

FIG. 16. A portable telescope. (Bausch and Lomb Optical Co.)

Anyone who has not used the smaller instrument will be greatly surprised at what may be done with it; many of the important contributions to descriptive astronomy having come from 2 and 3 inch objectives during the nineteenth century. It should also be remembered that the smaller instrument can frequently be used when atmospheric conditions render the larger glass useless.

Such a glass is, of course, not as powerful as the hundred-inch reflector on Mount Wilson. Not every object of which

we read can be seen with it, but that is equally true of a ten-inch telescope. A 60 mm. telescope will make it possible to see objects which are typical, and it will show them clearly and well. Objects are so numerous and interesting that there is no fear of running out of material for observation. A list of the general type objects is given:

Sun spots
Lunar phenomena including mountains and craters
Planets and their satellites
Double stars
Nebulae
Star clusters

There are also four classes of objects which offer an opportunity for valuable contributions. These are:

Novae
Variables
Comets
Meteors

Even the larger observatories cannot watch the whole sky at the same time, and serious observations and reports of these four classes of objects receive serious attention when forwarded to the nearest observatory.

The objects in the first group are of general interest, and change sufficiently to maintain a life-time of interest.

The following specific objects may also be seen:

PLANETS.

(1) The markings on the planet Jupiter
(2) The four moons of Jupiter
(3) The phases of Venus
(4) The phases of Mercury
(5) The rings of Saturn
(6) Titan, the largest satellite of Saturn

MOON.

Lunar topography such as:

Copernicus
Tycho

Alpine Valley
Cleft of Hyginus
Crater of Newton

and so on endlessly. These objects change constantly as the angle of light changes, and one never tires of going back and looking at the rugged mountains and their black shadows projecting out over lifeless plains.

SUN SPOTS.

These vary from day to day and are always worthy of study; being practically the only celestial objects which may be observed during school hours. The most satisfactory way of observing these is to allow the sun's image as it leaves the eyepiece to be projected upon a smooth sheet of white cardboard. The entire class may then observe the spots at the same time and there is no danger of the eye being injured.

DOUBLE STARS.

These are extremely interesting, as it is always a surprise to point the instrument at what is apparently a single star and then, when looking through the telescope, to find it has resolved into several. There are many doubles which cannot be "split" with a small telescope, since the power of resolution depends on the size of the objective.

However, a good 60 mm. glass under ideal conditions should "split" a pair of sixth magnitude stars, at least as close together as 3 seconds of arc and theoretically as close as 2 seconds of arc. This is more than ample to split such famous doubles as:

Mizar in Ursae Majors, 2 and 4 magnitudes (14 seconds apart)
E1 and E2 Lyrae, "The Double Double"
Beta Orion, 1st and 8th magnitudes, 9 seconds apart (this is a hard test)

STAR CLUSTERS.

These are curious gatherings or groupings of stars in clusters or galaxies. We know that their distance is tremendous, for all that we can see with the instruments is innumerable points

of light, and if we use a larger telescope we still see more points of light but just that and nothing more. Many of these star clusters are beautifully grouped and appeal to the aesthetic sense more than do any other celestial objects. The twinkling points of light frequently appear to have been placed in a definite pattern upon the black velvet background of the night sky. The astronomer Messier catalogued many of these star clusters, and the initial M before a number means that Messier discovered it. Some of the more beautiful clusters are:

M 1184
M 41
M 167
M 38 (This cluster is in Aurigae)
N 37 (Also in Aurigae)
H VI 33 and 34—The cluster in the sword handle of Perseus
The Pleiades

NEBULAE.

To gaze out across the millions of miles of trackless space and observe for the first time a far-flung mass of nebulous material folded and twisted like diaphanous drapery, and to realize the immensity of such a system is to obtain a new conception of man's place in the universe. The most pleasing nebulae to observe is the great nebulae in Orion. There are also

M 57 Lyrae which is the Ring Nebulae
M 27 Vulpeculae, the Dumbbell Nebulae

It should be remembered that the light from nebulae is very weak, and only a photographic plate exposed for a long period of time will show all the details which are present.

In beginning observation with a small instrument, the observer must first be familiar with the constellations. There need be no attempt to visualize the mythical figures by which they are represented, but the group of stars should be recognized on sight, no matter what time of the year it may be. This is necessary because the small telescope must be pointed at the object directly without the aid of hour circles. Right

ascension and declination are useless to help locate an object with a small telescope; its relation to other "sky marks" must be known.

Thus it is a good thing to begin with the naked eye observation, then view a few objects through an opera glass or binocular, and then pass on to the telescope. The student should be taught to find his way around in the sky and not merely be allowed to observe objects which he will not recognize or be able to locate a week later.

It should be evident, from these plain unexaggerated statements of what can be done with a small instrument, that a 60 mm. telescope is a valuable piece of equipment for the secondary school. In college work several small instruments can frequently be used when the atmospheric conditions are bad. Even in high schools where astronomy is not taught as a separate subject, a telescope should by all means be available for use in the general science classes. There is never any lack of student interest in such a course where observations are conducted frequently and where emphasis is placed on this phase of the work rather than merely memory work on distances and names.

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Science teachers interested in making small telescopes should procure a book published by the *Scientific American* called *Amateur Telescope Making*.

Chapter XVII

Projection Machines and Accessory Equipment

MOST picture-projecting devices whether they be slide, film, reflector, or motion picture machine consist of four main parts: (1) lamp-house, (2) picture carrier, (3) objective lens, and (4) screen. (See figure 17.)

The first three parts are built as a unit. A moment's inspection will suffice to see that they are intact. The screen may be any smooth, white opaque surface. Various kinds of screens are described on page 267.

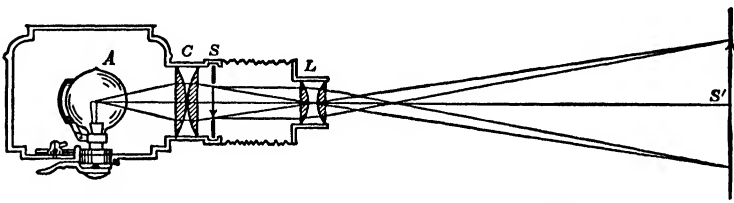


FIG. 17. The construction of a projector. *A*, incandescent lamp; *C*, condenser; *S*, picture carrier; *L*, objective lens; *S'*, screen. (From Black, *Introduction to College Physics.*)

THE STEREOPTICON OR SLIDE LANTERN

The slide lantern is a device used to project pictures from a glass slide to a wall or screen. The modern "American-made" slide consists of a piece of glass, 4 inches by 3¼ inches, upon which there is a plain or colored photograph or drawing. "European-made" slides are commonly 3¼ inches by 3¼ inches and they do not fit the "American-made" carriers.

The optical parts of most projectors are essentially the same. The lamp-house contains three parts. At the back of the lamp-house there is a *reflector* (a concave mirror) which reflects forward the light rays which would otherwise be lost. In front of the reflector there is an *incandescent lamp* which is the source of illumination. Ahead of the lamp, in the front part of the lamp-house, there is a *condenser* which is usually composed of

two or more convex lenses. The purpose of the condenser is to concentrate the light rays on the slide which rests in the picture carrier. At the extreme front end of the projector is the *objective lens* which throws a clear image of the projected picture on the screen. The objective lens must be moved backward or forward to adjust to the distance the projector is from the screen. The objective lens is therefore mounted on a sliding rack. On some projectors the space between the objective lens and the picture carrier is occupied by a leather bellows.

HOW TO SET UP THE SLIDE LANTERN.

1. First ascertain the characteristics of current you have in your school. Electricity is supplied in two forms: alternating current (AC) and direct current (DC). Current is also supplied at various voltages. Make sure that your machine will operate with the current available. Most city systems supply alternating current at 110 volts (110 V.) whereas the small individual plants for farm, home, or school use frequently supply direct current at 32 volts.

An incandescent bulb will operate equally well on either direct or alternating current. It must be used only with the proper voltage. The voltage for which the bulb is adapted is marked on the bulb.

An arc lamp operates best upon direct current, though arc lights are constructed for operation on alternating current. A D-C arc lamp will not operate well with A-C current, or vice versa. The necessary facts are usually stamped upon a metal label attached to the lamp or its connected parts. The arc lamp is not now commonly used.

2. Set the lantern on a firm table or other support, directed, as near as you can estimate, toward your screen.

3. Connect the plug at the end of the cable leading from the lamp-house, to the outlet or socket in the room.

4. Turn on the current and the lamp should light. Now adjust the position of your table and lantern until you get the brightest possible light falling within the margin of your

screen. The size of the picture can be controlled by moving the lantern toward or away from the screen.

5. Darken the room as much as possible by drawing the shades. Black curtains are desirable but not necessary. If translux or other daylight screen is used, it is not necessary to darken the room. However, in this case there must be no source of light other than the lantern in the *back* of the screen.

6. Select the slide and place it in the carrier. In order to make sure that the slides will appear on the screen right side

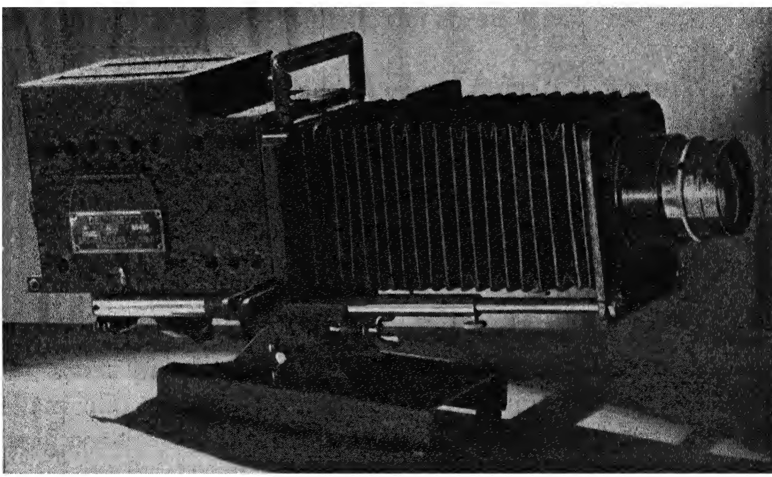


FIG. 18. A glass-slide projector. (Spencer Lens Co.)

up and with any printing correctly shown, proceed as follows: Face the screen (if using opaque screen) and hold the slide in position so that the picture appears as desired on the screen. Then rotate the slide to the left or right by 180° so that it is inverted, and drop it in the carrier. *Most slides are provided with a "thumb mark"* so placed that if the slide is turned with the mark in the upper right-hand corner when the operator faces the screen, the slide will be in proper position to drop in its carrier.

The picture will probably be out of focus. Try to focus by turning the thumbscrew on the lens mounting, or by ro-

tating the mounting if no screw is present. If the range of adjustment is not sufficient to secure sharp focus, set the adjustment at about the middle of its range and examine to see whether there is not some provision for changing the length of the bellows (if present) or otherwise moving the whole lens assembly farther from or closer to the slide carrier. If so, make an approximate adjustment for focusing. If not, move the entire lantern, closer to or farther from the screen until approximate focus is secured. Then complete the focusing for sharp detail by means of regular adjustment. Once carefully set, the focus needs no further attention during the lecture.

7. If using a daylight screen, the operator may use the same directions for orienting the slide, but he must stand with his *back* toward the screen. Focusing may offer some difficulty due to the dimness of the image, as seen from the operator's side. A piece of white opaque paper held against the screen is of assistance.

TYPES OF SLIDES.

In general there are four different types of glass slides.

1. *Photographic Slides.* A photographic slide is one made by transferring an image from a negative to a sensitized glass plate. The majority of slides sold by commercial firms are of this type.

If a teacher has the time and patience he can soon learn to make photographic slides. The techniques to be mastered and the apparatus and chemicals required are about the same as those required in amateur photography. An excellent little monograph giving detailed information regarding the making and coloring of lantern slides may be obtained from the Eastman Kodak Co., at Rochester, New York.

2. *Etched Glass Slides.* An etched glass slide is a piece of glass (4 in. by 3¼ in.) that has one side roughened by use of an acid or emery. The roughened side provides a surface upon which a diagram or drawing may be made with colored pencils, crayons, or ink.

Etched glass slides have several advantages. First, the diagram or outlines made upon them may be removed with soap and water thus permitting the slides to be used over again. Second, the slides are easy to use. If the picture is the proper size, one can lay the etched glass slide over the picture and trace in detail the outlines of the picture.

Dent [1] offers the following helpful suggestions for making etched glass slides:

"(1) If the picture to be reproduced is a free-hand drawing, it is advisable to draw it first on a piece of paper, $3\frac{1}{4} \times 4$ inches in size. If a picture is to be reproduced and is less than this size, it will not be necessary to make a sketch of it. If the picture is larger than the slide size, it is usually possible to select the important part of the picture and use it. The details of the picture should be kept within a space approximately $2\frac{1}{4} \times 3$ inches.

"(2) Lay the piece of etched glass on the drawing or picture and trace the details in outline with an ordinary medium or hard lead pencil. Mistakes in pencil may be removed with art gum.

"(3) Color the pictures with the lantern slide pencils.

"(4) If it seems desirable to preserve the picture for future use, place a piece of plain cover glass over the colored drawing and bind the edges with lantern slide binding tape. A piece of tape fifteen inches long is required to bind the glass all the way around. Wet the tape. Place it on a flat surface with the sticky side up. Hold the two glasses tightly together and place on edge in the middle of one end of the tape. Turn the glasses along the tape, being sure that the edges are being kept in the middle of the tape which will stick to the glasses. Then press the edges of the tape over the edges of the glasses and they will be bound securely.

"If the slide is not to be used over again, it will not be necessary to use the cover glass or binding tape. Furthermore, the pictures may be removed by using a little Dutch Cleanser or similar washing powder with water, or by using a lead pencil eraser on the dry glass. A small brush will be helpful if the slide is washed."

3. *Plain Pen and Ink Slides.* This type of slide may be made very quickly and cheaply by anyone. Ordinary, plain lantern

[1] Dent, E. C., *The Audio-Visual Handbook,* The Society for Visual Education, Inc.

slide cover glass may be used. The following are directions for making pen and ink slides:

Clean the glass slides by rinsing them in soap and water. Then rub them dry with a soft cloth.

Coat the slides with a thin coating of clean shellac or gelatin solution. Lantern slide kits, such as the Cambosco Quickway Lantern Slide Kit, provide a box of special slide coating material with directions how to use it. Stand the slide on edge until the coating is dry and hard.

Draw the diagram or picture. Place the prepared slide, coated side up, over the illustration selected. The subjects may be of the science teacher's own choice. Textbooks and magazines offer a wealth of illustrative materials such as pictures, charts, graphs, and diagrams.

If desired the slide may be colored. This is done with water colors. Pigment sheets, a palette box, and several water color brushes are the materials needed. If mistakes are made while drawing or coloring the slide simply wash the slide, recoat it, and begin again. The slide may be used over and over again.

When a teacher has made a slide which he wishes to keep permanently he should finish it in the following way: Frame the picture or diagram with a cut-out mat. Over the mat place a clean, uncoated lantern slide glass cover. Hold the two plates together evenly and place them in the center of gummed binding strip. Bind the edges with the binding tape.

4. *Cellophane Slides.* The cellophane slide consists of a small sheet of cellophane, 4 × 3¼ inches, bound between two pieces of plain lantern slide cover glass with binding tape.

A cellophane lantern slide is made in the following way: A piece of cellophane, 4 × 3¼ inches, is covered with a sheet of carbon paper and then typed through the carbon paper. The typing should be kept within space about 2¼ inches × 3 inches in size. The typed cellophane is then removed from the typewriter and carbon paper. It is then placed between two lantern slide cover glasses, and bound with binding tape.

The cellophane slide may be a useful tool for the busy science teacher. Outlines, assignments, and other matter

usually written on the blackboard may be prepared on cellophane slides and retained for repeated use.

THE OVERHEAD OR LECTURE TABLE PROJECTOR

This projector is designed for the teacher who wishes to stay at his desk, face his pupils, and operate his own machine. The machine is a modified lantern slide projector. It projects the regulation glass slide ($3\frac{1}{4} \times 4$ inches).

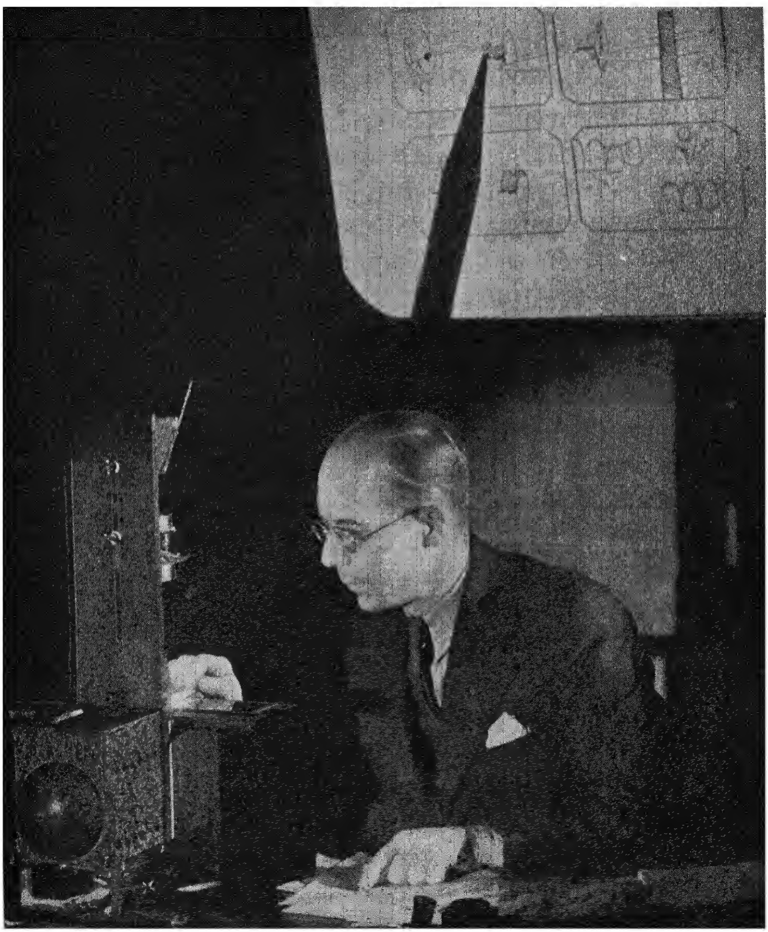


FIG. 19. An overhead projector. (Spencer Lens Co.)

This projector has several advantages over the ordinary lantern slide projector:

(1) The teacher may face his pupils and at the same time operate the projector.
(2) Changing slides is extremely simple because the slides are simply laid on the top of the slide track.
(3) Slides are placed on the slide track right side up. This enables the teacher to see the slide exactly as the pupil does.
(4) Special features in the picture may be pointed out by indicating with a pencil at the slide.
(5) The screen is overhead and is visible to everyone in the room.

THE OPAQUE PROJECTOR

In the lantern slide projector the picture is placed between the lamp and the projection lens. The light shines through the picture. If the picture is not transparent, it cannot be used.

The opaque projector (reflectoscope), on the other hand, is designed to use opaque (nontransparent) pictures such as photographs, drawings, picture postals, and cuts in books. Since the picture is opaque, the lamp is placed in front of the picture instead of behind it.

The place for the insertion of the picture is usually found at the back of the projector or at the bottom. Generally a spring is provided to hold the picture in place. These parts are constructed in such a manner as to allow the insertion of an entire book. This makes it possible to project illustrations from a book without removing pages. Special holders for small cards and postals are also provided. The cards may be fastened in the holders, which are slid through, somewhat like lantern slides.

Pictures must be inverted when inserted in an opaque projector. If the picture is reversed as to the right and left it will make little difference unless there is printing on the picture. In any case, nothing can be done about it as the reversal, if it occurs, is a characteristic of the lantern and cannot be changed. A reflectoscope which shows print correctly on an opaque or reflecting screen will show it reversed on a translux or daylight screen, and vice versa.

Focusing is done as in lanterns previously described, but requires more attention due to the fact that the pictures may not be perfectly flat and it may be necessary to refocus slightly at each change of picture.

It is necessary to use a high candlepower lamp in a reflectoscope and considerable heat is produced. It is, therefore, not

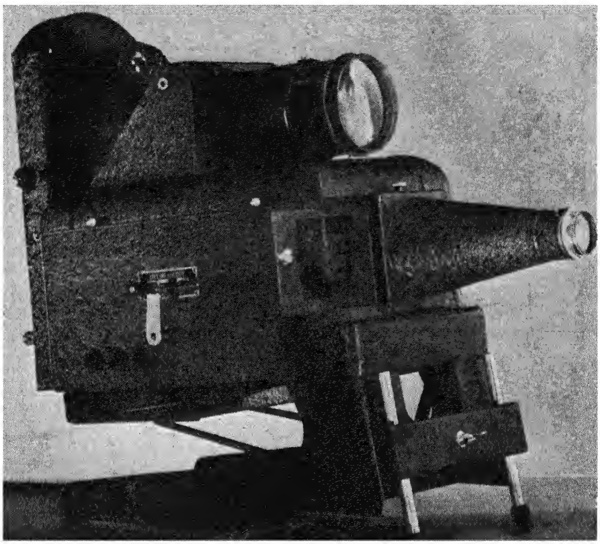


FIG. 20. A combination opaque and lantern slide projector. (Spencer Lens Co.)

wise to leave a picture in the lantern too long. Some of the more expensive models are equipped with an electric fan which keeps them relatively cool.

Many reflectoscopes are arranged to provide for projection of both opaque objects and lantern slides. The change from one type to the other is made by single movement of a lever. If you are using a combined lantern, see that the lever is set for the sort of projection you desire to use.

Schools that can afford but one type of projector should purchase the combination slide and opaque projection. Materials for use in it may be collected from many sources such as magazines, books, post cards, catalogues, and newspapers.

THE FILM SLIDE AND FILM SLIDE PROJECTOR

The film slide consists of a series of still pictures printed on a strip of noninflammable motion picture film or safety film. Still films have several advantages over glass lantern slides in that they are less expensive per picture, less bulky, and are not very easily broken. One strip of film usually contains from twenty to a hundred separate pictures. Various commercial

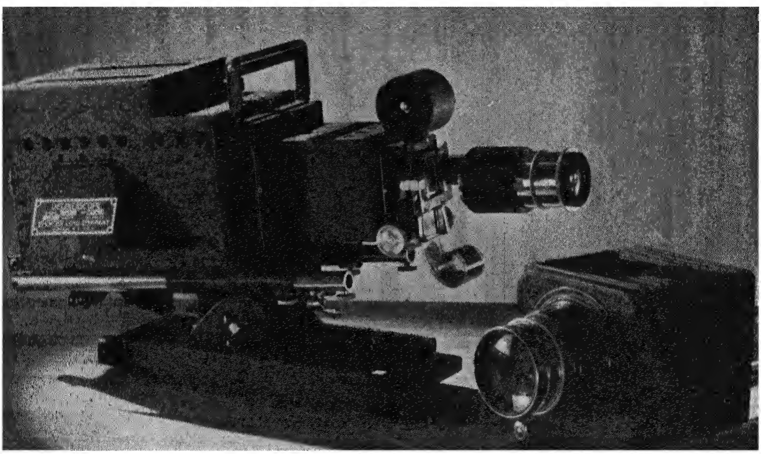


FIG. 21. A slide projector with a film slide projector attached. (Spencer Lens Co.)

companies have introduced film slides, under different names such as film slides, still films, and picturols.

Film slides have at least two disadvantages. One is that the pictures on a film are in a fixed sequence. It is possible, of course, to show the pictures in an irregular order by reversing the scenes as one may choose but this cannot be done very conveniently. Glass slides, however, may be placed in whatever order is desired before projection begins.

Perhaps the greater disadvantage lies in the fact that a limited amount of light must be passed through the film. There are two reasons for this: first, the picture on a film is much smaller than the picture on a slide and second, the heat from the brilliant illumination will warp or scorch the film.

Therefore a darker classroom is required for successful film slide projection than is required for the projection of glass lantern slides.

Film slide projectors are relatively inexpensive. They range in price from about $35.00 to $60.00. They are compact and light in weight. They may be connected with the ordinary electric light socket.

Schools which have a lantern slide projector (if it is the correct model) need not purchase a complete film slide projector. Bausch and Lomb Optical Company and the Spencer Lens Company have, on the market, film slide attachments which fit certain of their opaque and slide lantern projectors.

The film slide projector is easy to operate. The strip of film is inserted from the side instead of from above as is done with a glass slide. The film carrier must be examined to determine how it is opened to allow insertion of the film. Several types are in use. In all carriers toothed wheels are provided which engage the perforations at the edge of the films.

It is necessary to discover at which end of the film to begin. This is usually shown by the serial number on the beginning of the series. The picture is oriented in the same way as are glass slides. The roll of film is placed above the carrier and feeds downward. Focusing is done by moving the objective lens forward or backward. The objective lens is built on a sliding rack for this purpose.

A knob or some similar device is provided for advancing the film one picture at a time. With this there is a combined device for adjusting the "framing" of the picture; that is, to make the outline of the picture correspond with the lighted area of the screen.

THE MICROPROJECTOR

The microprojector is designed to project highly magnified images of tiny things such as bacteria, protozoans, and algae to the screen. This projector makes it possible for microscopic objects to be seen by the entire class and it enables the teacher to point out the features of special importance.

If the teacher owns a reasonably recent microscope, a microprojector designed for use with the microscope should be purchased.

In the most efficient microprojectors, illumination is provided by means of a clockwise feed arc lamp. The arc lamp

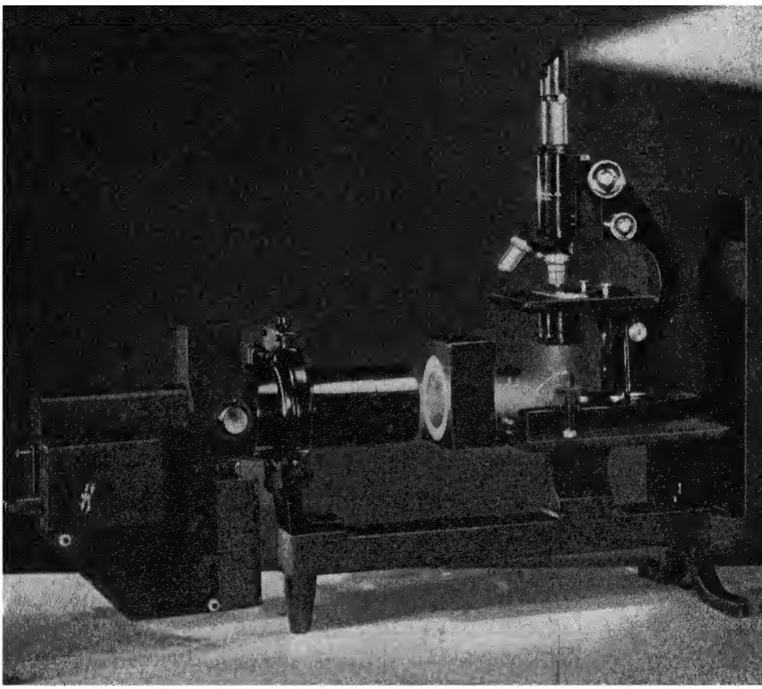


FIG. 22. A microprojector. (Bausch and Lomb Optical Co.)

operates in connection with a rheostat on either direct or alternating current. However, direct current seems to give better results than alternating current.

Schools that wish to project living material, such as a live amoeba or paramecium, to the screen should purchase a microprojector outfit that has a water cell. The water cell protects the specimens from the heat of the light beam.

Microprojectors are relatively easy to operate. Detailed directions for their use are furnished with the projector by the manufacturer.

THE EUSCOPE

The euscope is an apparatus that is used with any standard laboratory microscope. It serves three purposes:

(1) It permits individual observation of microscopic objects with both eyes. It fits closely over the eyepiece of the microscope and contains a prism which throws the image of a magnified object on a ground glass screen. It nearly doubles the magnification given by the microscope, and this tends to make work with the microscope less fatiguing.

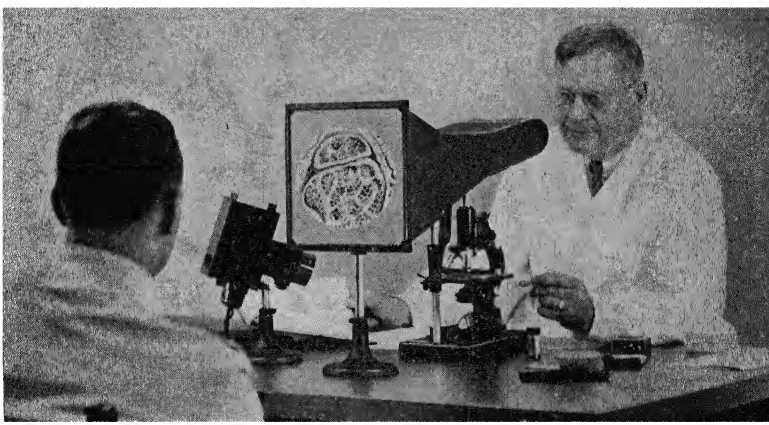


FIG. 23. A euscope. (Bausch and Lomb Optical Co.)

(2) The euscope may be used for microprojection work. A special viewing attachment is placed over the end of the euscope for this purpose. This makes the euscope very valuable for work with small groups of students. Students are able to observe the magnified objects while the teacher manipulates the microscope and points out the features to be observed.

(3) The euscope may be used for photomicrography. A special camera attachment which fits the euscope is necessary. The camera attachment converts the euscope into a photomicrographic camera for taking pictures of microscopic objects.

MOTION PICTURES

Motion pictures are taken with a motion picture camera. There is no essential difference between a motion picture

camera and a still camera expect that in the former, pictures are taken automatically at the rate of sixteen per second on a long narrow film. The film is moved into place back of the lens by a spring and remains stationary 1/32 of a second during exposure. A negative is developed from the exposed film, and a positive print is made from the negative. The positive

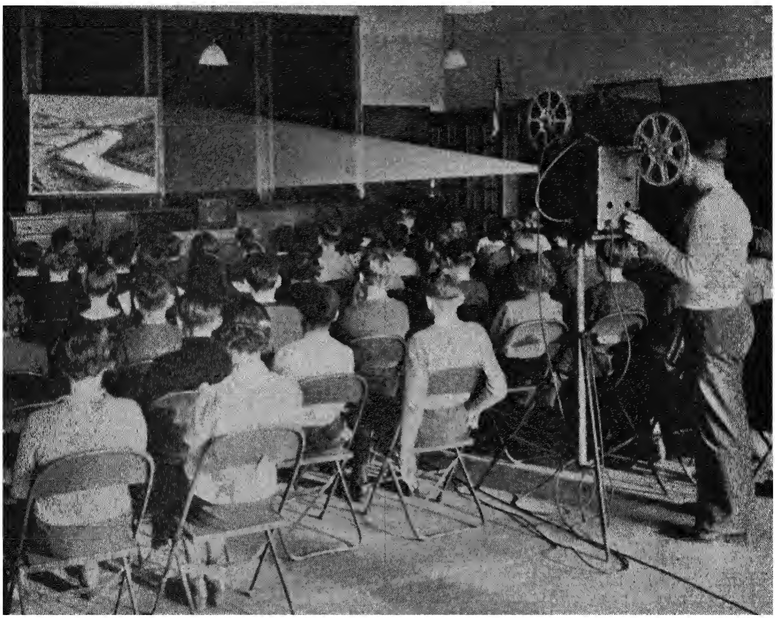


FIG. 24. A science class using a 16 mm. projector. (Bell and Howell Co.)

film is run through a motion picture projector while light passes through the film to a screen, upon which images of the original objects photographed are produced.

The motion picture is an optical illusion. Motion pictures are actually a series of still pictures. Human vision persists for a little less than a sixteenth of a second after an object has disappeared from view. The illusion of motion is obtained by projecting still pictures on the screen at the rate of sixteen pictures per second. The pictures in the projector are moved

forward by jerks. While the film is in motion the light is cut off by a shutter in the machine and at that instant the screen is dark. The eye, however, because of the persistence of vision, detects no period of darkness, but continues to see the picture which was visible the instant before. Before the vision of this picture dies out, another picture flashes on the screen and so on. Persistency of vision causes the individual still pictures to merge together and the human mind interprets them as motion.

The motion picture projector is a little more complicated than other types of projectors, but any teacher with a reasonable amount of mechanical aptitude can learn how to operate one and keep it in good working order. The optical parts to this projector are about the same as those found in a slide or still film projector. The motion picture projector has a lamphouse, picture carrier, and objective (projection) lens. In addition it has certain gears and gadgets which are necessary to furnish a continuous flow of film through the projector. A list of motion picture terms with definitions are supplied a little later for those science teachers who wish to become thoroughly conversant with motion picture terminology.

The following list of advantages and limitations of motion pictures has been compiled by McClusky [1] and others.

Advantages:

(1) The motion picture has the unique advantage of depicting action or behavior, with its irresistible illusion of life and reality. It is, however, an expensive visual aid and for that reason should be resorted to only when necessary (1) to show activity, which no other pictorial aid can portray, and (2) to provide such vicarious experiences as may be brought to students because they cannot get them in any other way.

(2) The film has proved valuable to scientific workers by enabling them to produce processes and analyze motion and movements for detailed study.

(3) The film has value in presenting popular nontechnical phases of the subject to those who have relatively little knowledge regarding it.

[1] McClusky, F. D., et al., "The Place of Visual Instruction in the Modern School." Syllabus of a proposed text.

(4) By means of the motion picture and the animated diagram, one can visualize the invisible.
(5) The motion picture is very effective in publicity drives, campaigns for social betterment, and similar forms of propaganda.
(6) The film is the best visual tool when the continuity of a process involving movement is to be seen.
(7) The film is advantageous for purposes of vivid summary or general survey of a broad topic.
(8) The film is unique in revealing, for the first time in the history of human learning, things which are too slow or too fast to be seen by the human eye.

Limitations:

(1) Motion pictures are expensive.
(2) The film with its rapid-fire method of projection must be stopped, slowed up, or shown a second or third time if any real study and analysis of the content is to be had.
(3) The moving picture in its present form and use has a tendency to relegate the teacher into the background.
(4) Few good films are available at reasonable cost.
(5) Films are perishable and do not stand wear and tear like other visual aids.
(6) The film, to be effective in the classroom, should be previewed by the teacher and followed up by a definite study. Often the teacher cannot get the film when it is most needed.
(7) The film is used too often as a substitute for, rather than as a supplement to, other methods of presentation.

Kinds of Film. There are two kinds of motion picture films in use in this country: the inflammable or theatrical film and the noninflammable or safety film. The inflammable type is used generally in theaters. It is made with a nitro-cellulose base which if exposed to intense heat burns very quickly. It is for this reason that states have regulations which require that this type of film be projected in fireproof projection booths.

Noninflammable or safety film is made of cellulose acetate, which, if exposed too long to the heat of a projector, blisters and shrivels. The heat of a projector is not intense enough to cause safety film to burst into a flame. Safety film is recommended for schoolroom use, because it does not need to be projected in a fireproof booth.

Motion picture film comes in two widths: 35 mm. film

and 16 mm. film. "MM" is an abbreviation for millimeters. 35 mm. film is about 1⅖ inches wide. There are 16 pictures or frames to a foot of film and there are about 1,000 feet of

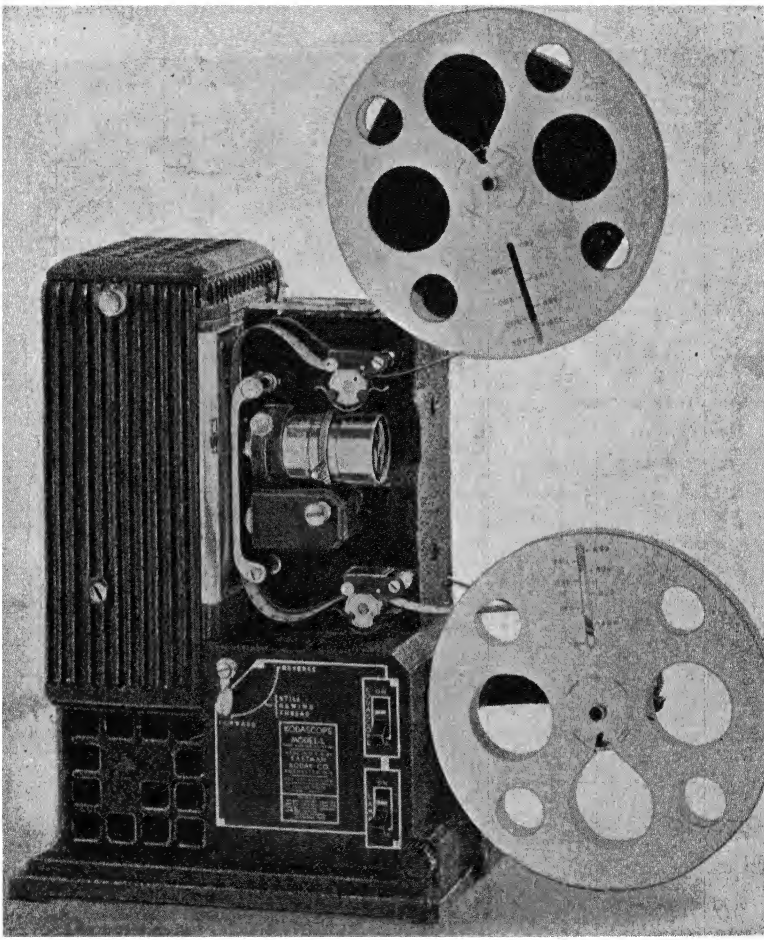


FIG. 25. A 16 mm. silent projector. (Eastman Kodak Co.)

film on a standard reel. With the projector running at average speed about fifteen minutes is required to show one reel of 35 mm. film.

Sixteen mm. film is about ⅗ inches wide. It has 40 pictures

or frames to a foot of film and there are 400 feet of film on a standard reel. About fifteen minutes is required to show one reel of 16 mm. film.

Sixteen mm. films are always printed on a cellulose acetate base. They may be used anywhere, anytime. There are no

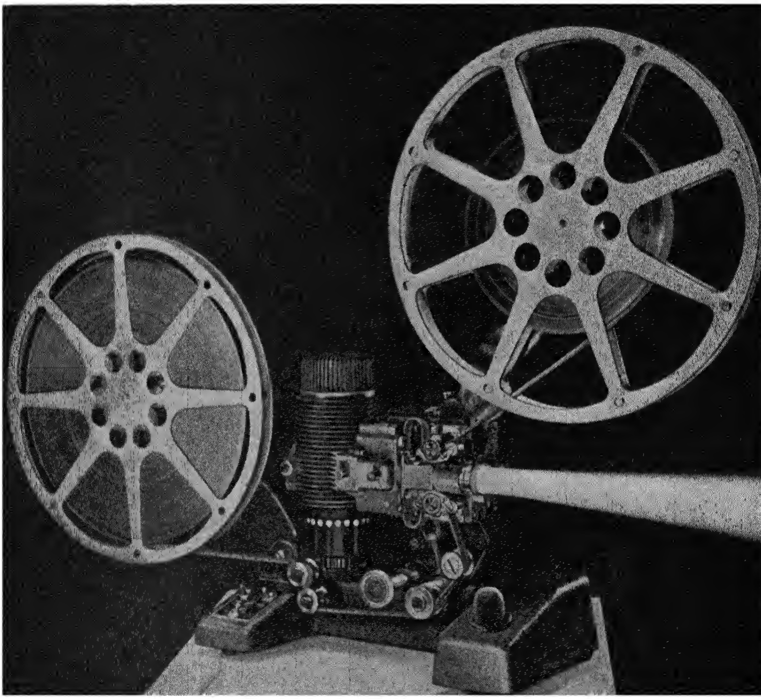


FIG. 26. A 16 mm. silent projector. (Bell and Howell Co.)

risks and no restrictions with 16 mm. film. Fireproof booths are not required.

Types of Projectors. Generally speaking there are two types of motion picture projectors: the standard theatrical projector and the portable projector. The large theatrical projector is used in theaters and large auditoriums. It must be installed in a fireproof booth in accordance with state regulations.

There are two different kinds of portable projectors: (1) the 35 mm. film projector and (2) the 16 mm. film projector. Six-

teen mm. film projectors are recommended for classroom use. They are smaller in size, weigh less, cost less, and they are easier to carry and operate than 35 mm. film projectors. The 16 mm. film projector is the ideal projector for schoolroom projection. If a school employs a 35 mm. projector in the classroom, care should always be exercised to see that safety film only is used.

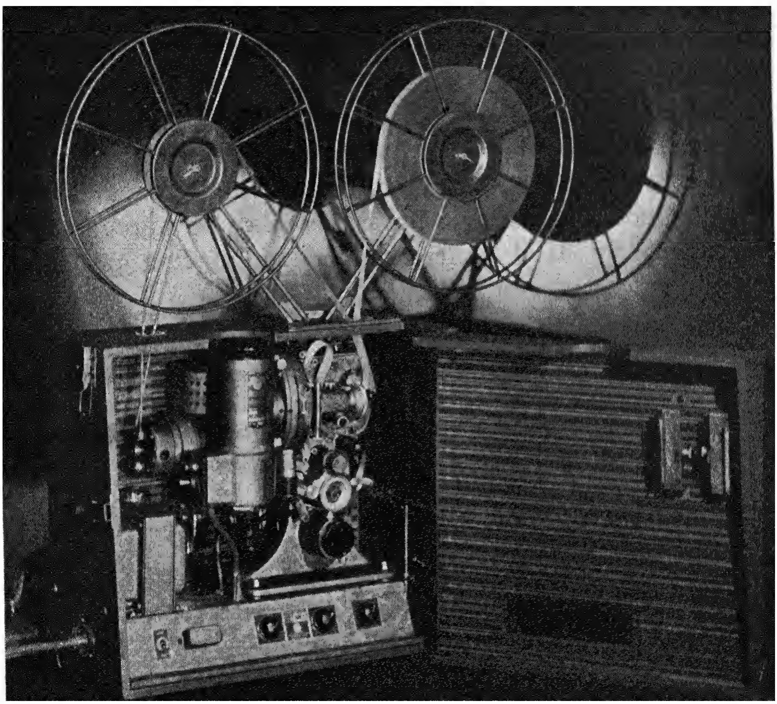


FIG. 27. A 16 mm. sound-film projector. (Victor Animatograph Corp.)

SOUND PICTURES.

Within recent years the educational talking pictures have been developed and they give much promise of being a valuable aid in the teaching of science and other school subjects. The manipulation of sound projection equipment is a little more complicated than the silent movie projector. However, a

teacher who has already learned how to use a silent movie projector can soon learn to operate the sound picture projector by following carefully the instructions provided with the projector.

The addition of sound to the silent movie has increased the range of usefulness of the motion picture projector. It provides an opportunity to bring into the classrooms nearly life-like reproductions of many objects and processes that exist or take place outside the schoolroom building. By means of sound pictures it is possible also to bring into the classroom demonstration lectures by eminent authorities in science and science education who would otherwise not be accessible.

Sound picture projection equipment and sound films are more expensive than silent picture movie projectors and silent films. Good silent movie projectors may be purchased for approximately $100, whereas good sound film projection equipment costs about $400.

LIST OF MOTION PICTURE TERMS.

Acetate film. Noninflammable or safety film. Where no suitable fireproof enclosure for the projector is available, only safety film may be used.

Condenser lens. A system of two plano-convex lenses placed between the film and the source of light to collect the rays of light and focus them on the film.

Exchange. A commercial agency from which motion pictures may be purchased or rented.

Film. A celluloid strip, coated on one side with a sensitive emulsion, upon which photographs are to be made; the developed negative and positive. The word is frequently used to indicate a certain motion picture or motion pictures in general; and it is sometimes used as a verb.

Film cement. A liquid medium, made of glacial acetic acid and amyl acetate, for patching and splicing motion picture films. Never use anything other than film cement for splicing film strips together.

Focus (noun). The point where rays of light passing through the lens converge.

Focus (verb). Adjustment of the lens in the projector so that the image upon the screen is sharp.

Footage. Number of feet in a film.

Frame-line. The black line that divides the top of one image from the bottom of another. When the pictures are being shown "out of frame" the line may be seen on the screen.

Frame (noun). A single photograph in a reel of film. In standard (theatrical) film each such photograph is 1 inch wide by ¾ of an inch high, and there are 16 distinct photographs to the foot. In normal projections 1 foot of film is thrown upon the screen each second. The rapid succession of images deceives the eye sufficiently to give the impression of actual motion.

Frame (verb). When the images in the film are not correctly aligned with the light in the projector, for instance, when the screen shows a man's legs and feet at the top and his trunk and head at the bottom the operator moves a lever to make the images register perfectly. This operation is called *framing*.

Inflammable film. *See* nitrate film.

Joining. Cementing parts of a film together.

Leader. Blank film at the beginning of a reel, placed there to aid the operator in threading the projector. Such film at the end of the reel is called the trailer.

Legends, titles, subtitles, captions. The interpretative words that explain the scenes.

Loop. A very important element in projection. Loops are the slack places left in the film at certain points when it is threaded through the projector, so that it can be jerked down one frame at a time without being damaged.

Negative. Film exposed in a camera and then developed by chemical reaction so that the image is brought out and made permanent. The blacks and whites of the image, however, are reversed. When a positive print is made from the negative, the blacks and whites are placed in their true relation.

Nitrate film. Inflammable film. Film that burns very rapidly when ignited.

Perforations. The holes on both edges of the film. In standard film there are 4 perforations on both sides of each frame.

Positive. Film exposed to the action of light behind a negative and then developed. A positive is the opposite of the negative. It is the image of the positive that is thrown on the screen by the projector.

Print. A positive film. As many prints as are desired can be made from a negative.

Printing. The process of acting upon positive film by passing it through a machine in company with a negative against a source of light.

Projection or objective lens. The lens that focuses upon the screen, the rays of light from the lamp.

Projector. A machine containing a powerful source of light and a mechanism that passes the film between the light and the lens which magnifies the image film and throws it upon the screen. Each frame, or image, in the film is halted for a fraction of a second in the path of the light and then moved on. This is called intermittent movement.

Reel. The spool upon which the film is wound for use in the projecting machine. A reel of 35 mm. film contains approximately 1,000 feet. A reel of 16 mm. contains about 400 feet. The projection of one full reel, requires, on the average, 15 minutes.

Release. To place a motion picture in distribution, the act of doing so, or the motion picture concerned.

Rewinder. The mechanism that reverses the winding of a film so that the beginning of the film will lie on the outside of the reel, dull side out, ready for projection.

Safety film. *See* Acetate film.

Safety shutter. In a projector the little door that falls between the lamp and the film when the machine stops or runs so slowly that there is danger of igniting the film.

Screen. The surface upon which the image is thrown.

Shutter. In projectors, the 2-wing or 3-wing revolving device that intercepts the light as the film is jerked down one frame at a time, and, by multiplying the flickers on the screen, tends to make them less apparent.

Splice. To join, by cementing, one piece of film with another.

Split reel. A reel containing two or more subjects under different titles.

Sprocket. The revolving toothed wheel which moves the film through the projector by engaging the perforations.

Take-up. In a projector, the mechanism used in winding the film after it passes the projecting aperture.

Thread. To pass positive film through the projector so that when the machine is operated the images will be thrown upon the screen, so that the film will wind properly from one reel to another.

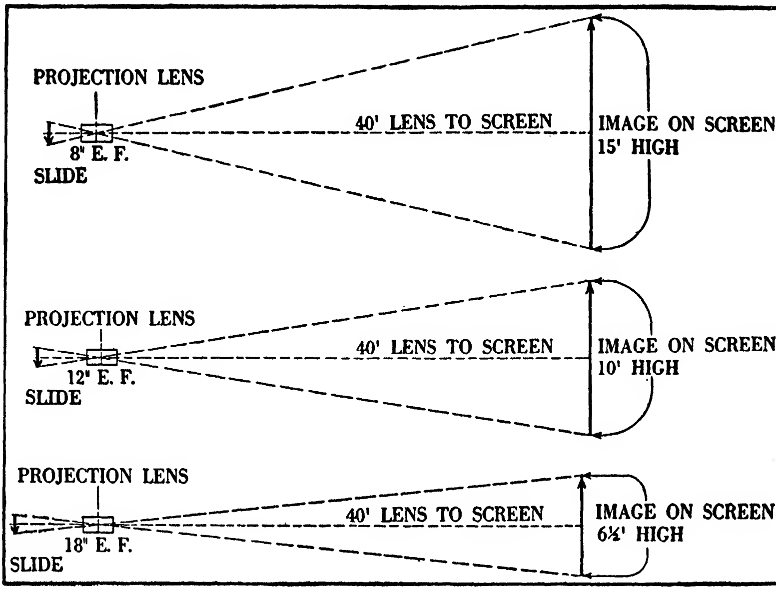
Throw. Distance from the projector to the screen.

PURCHASING PROJECTION MACHINES

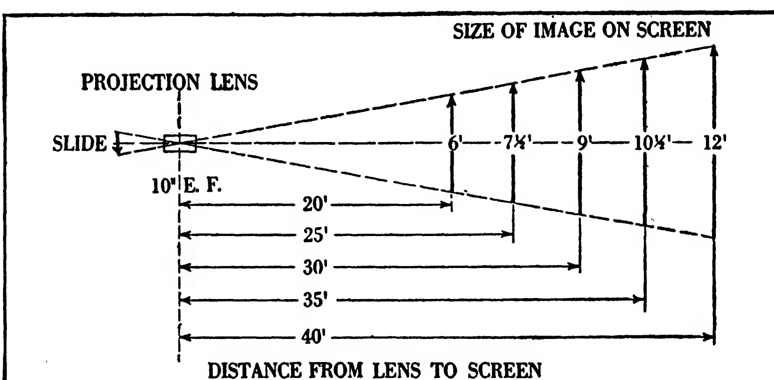
In purchasing a projection machine for the projection of opaque objects, still film, or lantern slides, it is important that the teacher select a machine with the *correct focal length of lens* to meet the conditions under which the machine will be used. The equivalent focal length (E. F.) of a lens or combination of lenses is the distance from the lens to a point at which all the rays coming from a distant object would form a sharp image. The focal length therefore is directly proportional to the distance from lens to screen and inversely proportional to the size of the image on the screen.

The three diagrams below illustrate how the size of the image on the screen is inversely proportional to the focal

length of the projection lens, when the distance between the lens and the screen remains constant.



The following diagram shows how the size of the image on the screen is directly proportional to the distance the image is from a given lens.



It is also important to keep in mind that the intensity of illumination per unit of area, varies inversely as the square

of the width of the picture. The larger the picture the less brilliant it will be.

After the teacher or administrator has established the two determining factors, the size of image desired and the distance the projector is to be placed from the screen, he need only refer to a table similar to the following one to find out the focal length of lens required for his particular situation.

TABLE 5

FOR LANTERN SLIDES, 2¾ × 3 INCH MAT OPENING

Focus of Lens in Inches	Distance from Lantern to Screen												
	15 ft.	20 ft.	25 ft.	30 ft.	35 ft.	40 ft.	45 ft.	50 ft.	60 ft.	70 ft.	80 ft.	90 ft.	100 ft.
6	7½	10	12½										
8	5½	7½	9½	11¼	13	15							
10	4½	6	7½	9	10½	12	13½						
12	....	5	6¼	7½	8¾	10	11¼	12½	15				
15	....	4	5	6	7	8	9	10	12	14	16½		
18	....	....	....	5	5¾	6½	7½	8¼	10	11½	13	15	16½
20	....	....	....	4¼	5	5¾	6½	7¼	8¾	10¼	11¾	13¼	14¾
22	....	....	....	....	....	5¼	5¾	6½	8	9¼	10½	12	13¼
24	....	....	....	....	....	4¾	5¼	6	7¼	8½	9¾	11	12¼

Example—A 10 inch lens used at a distance of 40 feet from the screen will project an image measuring 12 feet on its longer side.

SCREENS FOR USE WITH PROJECTION MACHINES

Successful projection of pictures is dependent in part upon having available a suitable reflecting or transmitting surface. With black-and-white slides, the blackboard may sometimes be used. A white or light-colored wall of the room, if suitable space is available, may function as a screen. Heavy white muslin or the back of a good spring-roller map will serve as a fairly efficient screen.

There are also various kinds of screens available which are sold under many different trade names. There are two main types of manufactured screens: (1) those which reflect the picture and (2) those which transmit the picture. The first type is called the reflecting screen and the second type is called the translucent or "daylight screen." With a reflecting screen the projector is placed in front of the screen at the

back or toward the back of the room. With a translucent screen the projector is placed back of the screen at the front of the room.

In addition to the cost of a manufactured reflecting screen there are two factors to be considered when buying such a screen: (1) the direct reflective power of the screen and (2) the largest angle to which the screen will reflect pictures satisfactorily.

Aluminum-Coated Screen. This is a canvas screen covered with a metallic coating of powdered aluminum. It reflects well, and its angle of reflection is about 30°. The aluminum-coated screen gives better results than the usual homemade screens in larger rooms where the projection distance is greater.

Beaded Screens. The surface of this screen is covered with small glass beads. This type of screen gives the highest direct reflection of light of all screens. It is limited in use, however, because it has a very small angle of reflection (about 8°). The beaded screen is recommended for use in situations where brilliant illumination is required and where the room is long and narrow. If the beaded screen is used in a short square room, the picture on the screen will appear distorted to those pupils who sit at the side of the room.

Mat-white Screens. This type of screen usually has a white silk surface which gives satisfactory reflection at wide angles from the reflecting surface. It gives a true reproduction of color which makes it a desirable type of screen to use with colored slides.

Translucent or "Daylight" Screens. The use of the term "Daylight" screen is apt to be confusing. It is well to remember that there is no screen which will give entirely satisfactory service when outside light is present to any great degree. As stated before, translucent screens are screens which transmit light from the reflector to the class. The projector is placed behind the translucent screen which usually stands on a tripod in front of the teacher's desk. To obtain the best results with this screen, it is necessary to have the room in semidarkness.

TROUBLES AND THEIR REMEDY

The teacher who uses projection machines will encounter difficulties at times. The following suggestions should prove helpful to teachers inexperienced with projection machines.

(1) Light out.
- (a) Current off. Test by turning on the room lights. If the room lights do not light up, a fuse may be burned out or the current may have been cut off temporarily by the electric company.
- (b) Switch may be turned off. Examine.
- (c) Lamp may not be firm in its socket. Give it a turn.
- (d) Filament in lamp may be broken. If so get a new lamp of proper wattage and voltage.
- (e) The wire in the cable may be broken. Have the cable tested.

(2) Will not focus.
- (a) The lamp may be too far from the lens or too close to the lens.
- (b) If there is a dark space at the top or the bottom of the picture the lamp may be too high or too low in relation to the lens.

(3) Picture not clear.
- (a) The slide may be too dark.
- (b) The room may not be dark enough. Dark curtains may be needed.

(4) Picture the wrong size.
- (a) If the picture is too large for the screen, move the lantern closer to the screen.
- (b) If the picture is too small for the screen, move the lantern farther away from the screen.

SOURCES OF PROJECTORS AND ACCESSORY EQUIPMENT

The science teacher should write to the following firms for free catalogues and descriptive materials. Some State Museums lend slides to teachers within their state. Write to your State Museum for information.

COMMERCIAL SLIDES

Academy of Science, Chicago.

American Museum of Natural History, New York.

Bailey Art Slide Co., 21 Lake Ave., Newton Center, Mass.

Biological Supply Co., 34 Union Square, New York.

Eastman Educational Slides, Iowa City, Iowa.

General Biological Supply House, 761 East 69th Place, Chicago.
Keystone View Company, Meadville, Pa.
Lick Observatory, Mt. Hamilton, Calif.
National Association of Audubon Societies, New York.
National Geographic Society, Washington, D. C.
National Park Service, Department of Interior, Washington, D. C.
National Studio's Inc., 226 West 56th St., New York.
Victor Animatograph Co., Davenport, Iowa.
Visual Education Service, Inc., 7024 Melrose Ave., Los Angeles, Calif.
Welsh, W. M., Manufacturing Co., 1516 Orleans St., Chicago.
Williams, Brown & Earle, Inc., 918 Chestnut St., Philadelphia, Pa.

SLIDE-MAKING MATERIALS. (plain glass slides, etched glass slides, mats, cover glasses, binding tape, cellophane, colored pencils, colored inks)
Cambridge Botanical Supply Co., Cambridge, Mass.
Celluloid Corp., 290 Ferry St., Newark, N. J.
Eastman Kodak Co., Rochester, N. Y.
Keystone View Co., Meadville, Pa.
National Theatre Supply Co., 90 Gold St., New York.
Radio Mat Slide Co., Inc., 1674 Broadway, New York.
Scarborite Colors, Inc., Scarborough-on-Hudson, N. Y.
Victor Animatograph Company, Davenport, Iowa.

SLIDE LANTERN PROJECTORS
Bausch and Lomb Optical Co., Rochester, N. Y.
Keystone View Co., Meadville, Pa.
Spencer Lens Co., Buffalo, N. Y.
Victor Animatograph Company, Davenport, Iowa.

THE OVERHEAD OR LECTURE TABLE PROJECTORS
Bausch & Lomb Optical Co., Rochester, N. Y.
Spencer Lens Co., Buffalo, N. Y.

OPAQUE PROJECTORS
Bausch & Lomb Optical Co., Rochester, N. Y.
Spencer Lens Co., Buffalo, N. Y.
Trans-Lux Daylight Picture Co., 247 Park Avenue, New York.

FILM SLIDE PROJECTORS AND ATTACHMENTS
Agfa-Ansco Corp., Binghamton, N. Y.
Bausch & Lomb Optical Co., Rochester, N. Y.
E. Leitz, Inc., 730 Fifth Ave., New York.
Society for Visual Education, 327 South La Salle St., Chicago.
Spencer Lens Co., Buffalo, N. Y.
Victor Animatograph Co., Davenport, Iowa.

FILM SLIDES
Bray Pictures Corp., 130 West 47th St., New York.
General Electric Co., Motion Picture Division, Schenectady, N. Y.

National Park Service, Department of Interior, Washington, D. C.
Nature Study Illustrated, San Jose College, San Jose, Calif.
Society for Visual Education, 327 South La Salle St., Chicago.
Spencer Lens Co., Buffalo, N. Y.
United States Department of Agriculture, Washington, D. C.
University Museum Extension Lecture Bureau, 10 South 18th St., Philadelphia, Pa.
Visual Instruction Service; University Museum, University of Pennsylvania, Philadelphia, Pa.
Visual Text Sales Company, Los Angeles, Calif.

Micro-Projectors and Euscopes

Bausch and Lomb Optical Co., Rochester, N. Y.
Spencer Lens Company, Buffalo, N. Y.

Motion Picture Projectors

Ampro Corporation, 2839 North Western Ave., Chicago.
Bell & Howell Co., 1801 Larchmont Ave., Chicago.
Eastman Kodak Co., Rochester, N. Y.
Herman A. De Vry, Inc., 1111 Center Street, Chicago.
International Projector Corp., 90 Gold Street, New York.
Victor Animatograph Corp., Davenport, Iowa.

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Hoban, C. F., Hoban, C. F., Jr., and Zisman, S. B., *Visualizing the Curriculum*, Cordon Co., 1937.

Oglesby, L. C., "The Still Camera in Biological Presentation," *The American Biology Teacher*, 1:131–33, 1939.

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Section III

Sources of Materials for Teaching Science

Part I

Sources of Flat Pictures

There follows a carefully selected list of sources of flat pictures which are useful in science teaching. The following is a key to the abbreviations heading the columns:

By . . . . Buy	Bi. . . . Biology
F . . . . Free	P . . . . Physics
GS. . . . General Science	C . . . . Chemistry

How Obtained		Description of Material	Suitable for			
By	F		GS	Bi	P	C
	x	Abrasives: Pamphlets on abrasives and their uses. For high schools and also elementary schools. Picture cut-outs for children included. Behr-Manning Corporation, Troy, N. Y.	x		x	x
	x	Aeronautical Mechanics: *The New 1000 H.P. Wright Cyclone Engine,* designed to show the mechanics of the airplane. Wright Aeronautical Corporation, Paterson, N. J.	x		x	x
	x	Air Conditioning: Several well-illustrated pamphlets on air conditioning in relation to refrigeration and weather. Also some "heat graphs." The Carrier Corporation, 850 Frelinghuysen Ave., Newark, N. J.	x	x	x	x
x*		Anatomy: Pictures of the human anatomy. Rand, McNally & Co., Chicago.	x	x		
x*		Astronomy: Pictures of observatory negatives from which lantern slides or prints can be made. Lick Observatory, Mount Hamilton, Calif.	x		x	
	x	Automotive: Bulletins describing the various types of Zenith carburetors. Zenith Carburetor Co., 696 Hart Ave., Detroit, Mich.	x		x	x

* Write for price list.

How Obtained		Description of Material	Suitable for			
By	F		GS	Bi	P	C
x*	x	Batteries: *The Story of Eveready Radio Batteries* available for general class distribution. National Carbon Company, Inc., 30 East 42nd St., New York.	x		x	x
$0.50 each set		Birds: Fifty post card pictures in color. In sets of four. Audubon Societies, 1974 Broadway, New York.	x	x		
$2.50 each set		Birds: Folder-sets of bird pictures. 106 subjects. Colored. State Museum, Albany, N. Y.	x	x		
	x	Birds: *Some Birds Useful to the Farmer.* Farmer's Bulletin No. 630. U. S. Department of Agriculture, Washington, D. C.	x	x		
x†		Birds and Flowers: Colored plates in sets. National Geographic Society, Washington, D. C.	x	x		
	x	Birds: Four different series of bird cards size 2″ × 3″ in colors. Church & Dwight Co., Inc., 70 Pine St., New York.	x	x		
	x	Bones of the Foot: A card showing the various bones of the foot. Size 9″ × 11″. Shelby Shoe Co., Portsmouth, Ohio.	x	x		
	x	Canned Food: A series of very interesting and well-illustrated colored pamphlets on the uses of canned foods. For teacher only. Write for list. National Canners Association, 1739 H St., N. W., Washington, D. C.	x	x		x
	x	Cement: Blue prints of construction projects. Also pamphlet, *Alpha Cement—How to Use It.* Write for educational material. Portland Cement Association, 347 Madison Ave., New York.	x			x

* *Fun with Dry Batteries*—a clear, nontechnical explanation of the dry battery with suggestions for toys, games. Price $0.10 for less than 25; $0.05 more than 25.

† Write for price list.

How Obtained		Description of Material	Suitable for			
By	F		GS	Bi	P	C
	x	Cement: Pamphlets describing the use of building materials such as stucco, brick, tile. Louisville Cement Co., Speed Building, 315 Guthrie Building, Louisville, Ky.	x			x
	x	Chain: Folders describing "Welded-Weldless Chain." American Chain & Cable Co., Inc., Bridgeport, Conn.	x		x	
	x	Chewing Gum: *Facts about Chewing Gum.* American Chicle Co., 30–30 Thomson Ave., Long Island City, N. Y.	x	x		
	x	Chewing Gum: Pamphlets and pictures on the making of chicle and chewing gum and products. Beech-Nut Packing Co., Canajoharie, N. Y.	x	x		
	x	Chicory: Description of the chicory industry in the U. S. E. B. Muller & Co., Port Huron, Mich.	x	x		
	x	Clothing: *Rayon,* a booklet describing the uses and manufacture of rayon. *The New and Revolutionary Things Being Done in Rayon.* Du Pont Co., 350 Fifth Ave., New York.	x	x		x
	x	Clothing: *The Story of Cotton Thread,* describing the manufacturing process of cotton thread. Well written for children. American Thread Co., 260 West Broadway, New York.	x	x		x
	x	Coffee: *The Story of the White House and Its Home Life,* excellent flat pictures depicting the raising and cultivating of coffee. Dwinnell-Wright Co., 311–319 Summer St., Boston, Mass.	x	x		x
	x	Coffee: *Coffee—How It's Grown and How to Make It,* especially prepared for classroom use and traces the production of coffee from plantation to packing. Hills Bros. Coffee, Inc., 2 Harrison St., San Francisco, Calif.	x	x		x

How Obtained		Description of Material	Suitable for			
By	F		GS	Bi	P	C
	x	Cork: *The Story of Cork.* Armstrong Cork Products Co., Lancaster, Pa.	x	x		x
	x	Corn: *Corn in Industry,* a booklet showing the products made from corn refining. Corn Industries Research Foundation, 270 Broadway, New York.	x	x		x
	x	Corrosion Resisting Equipment: General catalogue describing some of the equipment built for corrosive service from various alloys. The Duriron Co., Dayton, Ohio.	x		x	x
	x	Dental Hygiene: *The Importance of Vigorous Mastication,* giving the importance of exercise on the teeth and gums. American Chicle Co., 30–30 Thomson Ave., Long Island City, N. Y.	x	x		
	x	Dental Hygiene: *Simple Rules for Mouth Hygiene,* some excellent flat pictures on the care of the teeth. Supplied with a Teachers' Manual. Tek Tooth Brush Division, Johnson & Johnson, New Brunswick, N. J.	x	x		
	x	Drawing Instruments: A booklet on the use and care of drawing instruments. Eugene Dietzgen Co., 218 East 23rd St., New York.	x		x	
	x	Extracts: Booklets describing extracts and spices. D. and L. Slade Company, Boston, Mass.	x	x		x
	x	Fire Alarm Systems: A series of pamphlets describing various fire alarm systems. American District Telegraph Co., 155 Sixth Ave., New York.	x		x	x
	x	Fire Prevention: *Grinnell Duraspeed Sprinkler* *Grinnell Quartzoid Bulb Sprinkler* *Automatic Fire Protection* *Is Your School a Fire Trap?* Grinnell Co., Providence, R. I.	x	x	x	x

How Obtained		Description of Material	Suitable for			
By	F		GS	Bi	P	C
	x	Flour: *The Story of Flour*, a very interesting and well-illustrated booklet on the production of flour. Pillsbury Flour Mills Co., Minneapolis, Minn.	x			x
	x	Foods: *The Story of Chocolate and Cocoa.* Chocolate Sales Corporation, 19 East Chocolate Ave., Hershey, Pa.	x	x		x
	x	Foods: *Royal Cook Book* *Behind the Scenes with Royal* *What Do You Really Know about Bread?* *Royal Desserts and Salads* and other pamphlets available if a front of a package of either Royal Gelatine or Pudding is included. Standard Brands, Incorporated, 595 Madison Ave., New York.	x	x		x
	x	Foods: *Hot Cereal Studies for Health Classes* includes lesson plans for teaching the growing of a grain of wheat. Ralston Purina Co., St. Louis, Mo.	x	x		x
	x	Foods: Pamphlets showing the work of the meat-packing industry. Armour & Co., Union Stock Yards, Chicago.	x	x		x
	x	Foods: Shredded wheat picture-story card series for children. Can be colored. National Biscuit Co., Niagara Falls, N. Y.	x	x		x
	x	Foods: A series of small booklets giving excellent information on health and nutrition. Cookery and Facts about Cereals. Kellogg's, Home Economics Department, Battle Creek, Mich.	x	x		x
	x	Forests: *The Function of Lumber Mills.* Good views. 24″ × 36″. National Lumber Manufacturers Assoc., 702 Transportation Building, Washington, D. C	x	x		

How Obtained		Description of Material	Suitable for			
By	F		GS	Bi	P	C
	x	Grain: Pamphlets on the prevention of grain "rust" with samples of the Barberry bush. Conference for the Prevention of Grain Rust, Donald G. Fletcher, Ex. Secy., 300 Lewis Building, Minneapolis, Minn. For samples of the bush, write: Mr. L. K. Wright, State Director of Barberry Education, 303 Botany Building, State College, Pa.	x	x		
	x	Gypsum: Pamphlet, *The Red Book*, showing building materials made of gypsum. 1937 Edition. U. S. Gypsum Co., 300 West Adams St., Chicago.	x			x
	x	Gypsum: The following literature available: *Brief on Gypsum Plaster* *Fire Resistance of Gypsum Plaster* *Gypsum—A Non-Metallic Material* and other publications. Gypsum Association, Attention: H. J. Schwein, Sec., 211 West Wacker Drive, Chicago.	x			x
	x	Harvesting Scenes: Scenes in picture form. J. I. Case Threshing Machine Co., Racine, Wis.	x	x	x	x
x*		Health Education Publications: A series of pamphlets on child health education. National Education Association of the U. S. 1201 Sixteenth Street, N. W., Washington, D. C.	x	x	x	x
	x	Health Education Publications: Booklet form of famous paintings on health subjects. Metropolitan Life Insurance Co., New York.	x	x	x	x
	x	Health and Disease Prevention: Many interesting topics on health. Metropolitan Life Insurance Co., 1 Madison Ave., New York.	x	x		x
	x	Home Insulating: A very well-illustrated pamphlet on interior insulation of homes and offices by the use of cane insulating board. The Celotex Corporation, 919 North Michigan Ave., Chicago.	x		x	

* Write for price list.

How Obtained		Description of Material	Suitable for			
By	F		GS	Bi	P	C
	x	Ink: *The Art of Writing* *The Story of a Waterman's.* L. E. Waterman & Co., 191 Broadway, New York.	x		x	x
	x	Insects: *Common Insect Enemies of Man.* The McCormick Sales Co., Baltimore, Md.	x	x		
	x	Instruments: Pamphlets on various types of scientific instruments such as thermometers, humidifiers. Taylor Instrument Co., 95 Ames St., Rochester, N. Y.	x	x	x	x
	x	Lighting: *The Lighting Book*, a very exhaustive treatise on the subject of good lighting. Curtis Lighting, Inc., 1123 West Jackson Boulevard, Chicago.	x	x	x	
	x	Lime: Pamphlets on lime and kilns. American Lime and Stone Co., Division, Warner Co., Bellefonte, Pa.	x			x
	x	Linen Rugs and Carpets: Several pamphlets and flat pictures showing methods of home decoration with various styled rugs and carpets. The Klearflax Linen Looms, Inc., 295 Fifth Ave., New York.	x	x		x
	x	Linoleum: *The Story of Linoleum* Armstrong Cork Products Co., Lancaster, Pa.	x			x
	x	Linoleum: *The Story of Sealex Linoleum* picturing the production of linoleum. Congoleum-Nairn, Inc., Kearny, N. J.	x			x
	x	Locomotives: *The Modern Trends in Railway Motive Power*, illustrating the development of various locomotives both steam and electric. American Locomotive Co., 30 Church St., New York.	x		x	

How Obtained		Description of Material	Suitable for			
By	F		GS	Bi	P	C
	x	Malted Milk: Literature on malted milk, its uses and how it is made. Also a children's weight-table given. Horlicks Malted Milk Corporation, Racine, Wis.	x	x		x
	x	Marble: *Miracles in Marble*, describing quarrying and production of marble. Vermont Marble Co., Proctor, Vt.	x			x
	x	Matches: *The Romance of the Match*, giving the manufacture of the match. *Fifty Years of Match Making*, well-illustrated pictures showing the progress of the match industry. The Diamond Match Co., 30 Church Street, New York.	x	x		x
	x	Meters: Monograms B–7 and B–8 describing the internal action of the movable coil and movable iron types of electrical instruments. Weston Electrical Instrument Corp., Newark, N. J.	x		x	
	x	Oil: *The Sinclair Dinosaur Book*, excellent pictures in color. *Lubricating Farm Equipment* *Sinclair Dinosaur Stamp Album* Sinclair Refining Co., 630 Fifth Ave., New York.	x	x		x
	x	Paint: *Why Paint Peels*, a treatise on paint, varnish, and lacquer. National Paint, Varnish & Lacquer Assoc., 2201 New York Ave., N. W., Washington, D. C.	x			x
	x	Paper: *Making Expressive Strathmore Papers*, a monograph on the manufacture of paper. Strathmore Paper Co., West Springfield, Mass.	x	x		x
x*		Photographs: Photographs of scientists on post cards or larger sizes. Science Service, 21st and B Sts., Washington, D. C.	x	x	x	x
$0.03 each		Pictures: Pictures of scientists, birds, flowers, fruits, insects, fishes, and others. Natural colors. Size 7″ × 9″. Perry Pictures, Malden, Mass.	x	x	x	x

* Write for catalog.

How Obtained		Description of Material	Suitable for			
By	F		GS	Bi	P	C
	x	Pins: Sheets discussing the manufacture of pins. Oakville Company Division, Scoville Manufacturing Co., Waterbury, Conn.	x			
x*		Portraits: Portraits of scientists. Open Court Co., Chicago.	x	x	x	x
x†		Post Cards: Tuck's Famous Post Cards—showing landscapes, gardens, and flowers. William H. Dudley, Old Fresh Pond Road, Brooklyn, N. Y.	x	x		
$1.25 set of 40		Post Cards: Photostint post cards on nature study and other subjects. Detroit Publishing Co., Detroit, Mich.	x	x		
	x	Radio: Literature and pictures of tubes and radio sets. R. C. A. Manufacturing Company, R. C. A. Victor Division, Camden, N. J.	x		x	x
	x	Rubber: *A Wonder Book of Rubber*, three to any school. Not furnished to pupils. B. F. Goodrich Co., Attention: H. W. Klaxon, Mgr., Akron, Ohio.	x	x		x
	x	Rubber: *The Story of the Tire*, showing the development and manufacture of a tire. Goodyear Tire & Rubber Company, Inc., Attention: Mark L. Felber, Adv. Dept., Akron, Ohio.	x	x		x
	x	Salt: A comprehensive booklet on salt. Diamond Crystal Salt Company, Inc., St. Clair, Mich.	x	x		x
	x	Silk: Teaching aids concerning silk and the silk industry. Belding-Hemingway-Corticelli, 119 West 40th St., New York.	x	x		x

* Write for price list and sizes.
† Write for catalog.

How Obtained		Description of Material	Suitable for			
By	F		GS	Bi	P	C
	x	Silk: *The Story of Silk* Frutchey Silk Shop, 574 Fifth Ave., New York.	x	x		x
	x	Steel: Pamphlets #6, 7, 8, 9, 10 on safety, sanitation, and welfare of steel employees. Also *The Story of Steel.* U. S. Steel Corporation, 71 Broadway, New York.	x	x		
	x	Steel: Publications on the uses of steel in various industries and the manufacturing of steel. Allegheny Steel Co., P. O. Box F, Brackenridge, Pa.	x	x	x	x
	x	Stone: *Barre,* a booklet describing stone quarries and products. Barre Quarriers Cooperative, Inc., Barre, Vt.	x		x	x
	x	Storage Batteries: Monograph III telling about the Nickel-Iron-Alkaline Storage Battery. Thomas A. Edison, Edison Storage Battery Division, West Orange, N. J.	x		x	x
	x	Sugar: *Behind Your Sugar Bowl,* illustrating in colors the story of the manufacture of sugar. California-Hawaiian Sugar Refining Corp., 215 Market St., San Francisco, Calif.	x	x		x
	x	Tools: Pamphlets on saws, files, and tools. Henry Disston & Sons, Phila., Pa.	x		x	
x*		Visual Education Publications: Complete list of government printed matter. U. S. Government Printing Office, Attention: Pub. Dept., Washington, D. C.	x	x	x	x
	x	Watches: Pamphlets showing the various parts of watches and their styles. Waltham Watch Co., Waltham, Mass.	x		x	
	x	Water: *The Story of Water* *Mokelumne Water.* Booklets showing filtration methods. East Bay Municipal Utility District, 512 Sixteenth St., Oakland, Calif.	x	x	x	x

* Write for Price List #31 "Education."

How Obtained: By	How Obtained: F	Description of Material	Suitable for: GS	Bi	P	C
	x	Water Softening: A technical pamphlet on the softening of water to accompany the apparatus for demonstrating the softening of water. The Permutit Co., 330 West 42nd St., New York.	x			x
x*		Weather: Publications available on weather. U. S. Department of Agriculture, Weather Bureau, Superintendent of Documents, Washington, D. C.	x	x	x	x
$0.15		Weather: *Weather Series for the Amateur,* pamphlets covering the thermometer, barometer, compass in relation to weather forecasting. *Weather,* a book of 144 pages fully illustrated. $1.00. Taylor Instrument Co., 95 Ames St., Rochester, N. Y.	x	x	x	x
$0.50		Wild Animals: Photographs of wild animals in captivity. Large variety. N. Y. Zoological Society, Bronx Park, New York.	x	x		
$0.25 a doz.		Wild Flowers: Post cards of habitats in colors. Wild Flower Preservation Society, 3740 Oliver St., N. W., Washington, D. C.	x	x		
$0.25		Wild Flowers: Set of 12 colored post cards of wild flowers. American Museum of Natural History, 77th St. & Central Park West, New York.	x	x		
$0.02 per set		Wild Flowers: Twenty (20) small colored cards with explanation on the back. Advertising Department, Coca Cola Co., Atlanta, Ga.	x	x		
	x	Wood: Pamphlets on the various types of walnut wood and how used. American Walnut Manufacturers Assoc., 616 South Michigan Boulevard, Chicago.	x	x		x

* Write for price list.

Part II

Sources of Models, Exhibits, Specimens, and Objects

There follows a carefully selected list of sources of objects, specimens, models, and exhibits. Most of these materials have been examined by one or more of the authors to make certain that they are useful in science teaching. The following is a key to the abbreviations heading the columns:

By . . . . Buy
F . . . . Free
GS. . . . General Science
Bi. . . . Biology
P . . . . Physics
C . . . . Chemistry

How Obtained		Description of Material	Suitable for			
By	F		GS	Bi	P	C
$1.50		Abrasives: Samples of abrasive stone and abrasive paper. Behr-Manning Corporation, Troy, N. Y.	x		x	x
	x*	Aluminum: An educational set entitled, *Short Story of Aluminum*, containing specimens of the raw material and series of stamping illustrating the manufacture of an aluminum article. Aluminum Goods Manufacturing Co., Manitowac, Wis.	x		x	x
	x	Asbestos: An exhibit of samples of asbestos and how asbestos is used. Very instructive. Johns-Manville, 22 East 40th St., New York.	x	x	x	x
	x	Batteries: Eveready "Ignitor," 6-inch dry cell model available in limited quantity for physics and electrical classes. A very valuable model to have. Eveready Products, National Carbon Co., 30 East 42nd St., New York.	x		x	x
$0.50		Blanket Making: *Esmond Educational Exhibit*, size 12″ × 4″ × 1½″, containing samples of the raw materials and showing steps in the process of blanket making. The Esmond Blanket Mills, Esmond, R. I.	x	x		x

* Only to schools which will use the exhibit.

How Obtained		Description of Material	Suitable for			
By	F		GS	Bi	P	C
$0.50		Cement: Exhibition display set of eight (8) bottles containing raw and finished products. Universal Atlas Cement Co., 208 South LaSalle St., Chicago.	x			x
	x	Coffee: An exhibit containing a series of pictures of the manufacture of coffee from Brazil. Excellent for projecting. Dwinell-Wright Co., 311–319 Summer St., Boston, Mass.	x	x		x
	x	Cooking Utensils: "Wear-Ever" Aluminum Educational Exhibit containing apparatus for performing conductivity of heat experiment. Aluminum Cooking Utensil Co., New Kensington, Pa.	x		x	
$2.00 F. O. B.		Cork: An exhibit of the various types of cork. Armstrong Cork Products Co., Lancaster, Pa.	x			x
$1.00 for both		Corn Exhibits: 1. Samples in nine (9) test tubes mounted on an 8″ × 16″ flow-chart, showing corn derivatives and their uses. 2. A chart, 24″ × 36″, with ten (10) bottles containing samples of corn products. Corn Industries Research Foundation, 270 Broadway, New York.	x	x		x
	x	Corn Flakes Exhibit: Five (5) bottles containing samples of materials used in making corn flakes. Kellogg's, Battle Creek, Mich.	x	x		x
	x	Corrosive Resisting Equipment: A panel giving brief descriptions of special acid-resisting alloys with attached samples. The Duriron Company, Inc., Dayton, Ohio.	x		x	x
$1.50		Fibers: A cloth bound exhibit of jute fiber; samples of raw jute; the goods in process of manufacture and some of the goods as sold. Ludlow Manufacturing Co., 80 Federal St., Boston, Mass.	x	x		x

How Obtained		Description of Material	Suitable for			
By	F		GS	Bi	P	C
	x	Fire Protection: Sample "Duraspeed" sprinkler. Very instructive. The Grinnell Co., Auburn Plant, Cranston, R. I.	x		x	x
$3.00 net		Flax: Educational specimen cabinet showing flax in different stages of manufacture. The Linen Thread Company, Inc., 60 East 42nd St., New York.	x	x		x
	x	Flour: "Hecker's Educational Exhibit," for domestic science classes in New York State only. Hecker Jones Jewell Milling Division, 40 Corlears St., New York.	x	x		x
	x	Food: An aviation project in foods. H. J. Heinz Co., Pittsburgh, Pa.	x	x		x
$5.00		Food: "Slade's Educational Exhibit," giving 37 vials of different kinds of seeds and spices D & L Slade Co., 181–191 State St., and 86–88 Central St., Boston, Mass.	x			x
$11.85		Gas Engine Model: A demonstration four-cycle engine with miniature lamp. W. M. Welch Scientific Company, Chicago, Illinois.	x		x	
	x	House Insulation: Samples of wall-insulating material of various types. Celotex Corporation, 919 North Michigan Ave., Chicago.	x		x	
		Ink: "Process Manufacture Exhibit" showing the steps in the manufacture of the rubber which controls the flow of ink, with the pyroxylin plastic material now used. L. E. Waterman Company,* 191 Broadway, New York.	x			x
$1.00		Interior Decorating: Interior decorating exhibit of several pieces of fabric with actual pieces of drapery material and wall papers. The Klearflax Linen Looms, Inc. 295 Fifth Ave., New York.	x	x		

* Loaned by local Waterman dealer only.

How Obtained By	How Obtained F	Description of Material	Suitable for GS	Suitable for Bi	Suitable for P	Suitable for C
	x	Lime: Two bottles of limestone. American Lime and Stone Co., Bellefonte, Pa.	x		x	x
$0.50		Linen: "Educational Process Exhibit" showing linen in all stages of manufacture. Appended notes. The Klearflax Linen Looms, Inc., 295 Fifth Ave., New York.	x	x		
$1.00 F. O. B.		Linoleum: An exhibit of various types of linoleum. Armstrong Cork Products Co., Lancaster, Pa.	x			x
$0.50 each		Marble: Samples of Vermont marble in color, 6″ × 4″ × 3/8″ polished face. Complete set of eight (8) samples $4.00. Vermont Marble Co., Proctor, Vt.	x			x
	x	Oil: Educational exhibit of six (6) bottles of oils and waxes. Sinclair Refining Co., East Chicago, Ind.	x			x
x*		Paper: Several educational displays of paper, as well as packets and bottles. Advertising Dept., Hammermill Paper Co., Erie, Pa.	x	x		x
$1.00		Paper: Educational exhibit consisting of four (4) mounted bottles of paper in various stages of manufacture. Described. Strathmore Paper Co., West Springfield, Mass.	x	x		x
	x	Pens: Card containing samples of the different stages of the manufacture of steel pens. Very instructive. The Esterbrook Steel Pen Manufacturing Co., Camden, N. J.	x		x	
$0.50		Pins: "Puritan Pin Exhibit" outlining the manufacture of Puritan pins. Oakville Co., Division, Scoville Manufacturing Co., Waterbury, Conn.	x		x	

* Prices variable. Write for list.

How Obtained		Description of Material	Suitable for			
By	F		GS	Bi	P	C
	x	Plastics: Samples of rod, sheet, and finished plastic material in color. Very interesting. American Plastics Corporation, 50 Union Square, New York.	x			x
	x	Rubber: "From Plantations to Highways," an exhibit on rubber. Only one supplied to a school. Not supplied to pupils. B. F. Goodrich Co., Attention: H. W. Klaxon, Mgr., Akron, Ohio.	x	x		x
$1.75		Rubber: Exhibit of the various steps in tire construction together with actual samples from the crude rubber to the finished tire. Size 22″ × 28″. Goodyear Tire and Rubber Co., Inc., Akron, Ohio.	x	x	x	x
$0.60		Rubber: An educational exhibit. Hood Rubber Co., Inc., Attention: P. N. Swaffield, Watertown, Mass.	x	x	x	x
	x	Rubber: Samples of materials. Firestone Tire and Rubber Co., Firestone Park, Akron, Ohio.	x	x		x
x*		Silk: Cultures and exhibits of various kinds. T. A. Keheler, P. O. Box 141, Franklin Station, Washington, D. C.	x	x		x
$2.50		Silk: Teachers Silk Cabinet containing cultures. Belding-Hemingway-Corticelli Mills, Putnam, Conn.	x	x		x
$4.00 to $5.00		Sponges: Samples of sponges in small boxes with attached story. "Live" sponges in jars of preservative fluid. Schroeder & Tremayne, Inc., 500 North Commercial St., St. Louis, Mo.	x	x		

* Price variable. Write for list.

How Obtained		Description of Material	Suitable for			
By	F		GS	Bi	P	C
	x	Sugar: A display case showing various bottles of different types of sugar. California-Hawaiian Sugar Refining Corporation, Limited, 215 Market St., San Francisco, Calif.	x	x		x
$1.50		Thimbles: "Thimble Exhibit," showing various stages in the manufacture of thimbles. Oakville Co., Division, Scoville Manufacturing Co., Waterbury, Conn.	x		x	
	x	Water Softening: Apparatus for demonstrating the softening of water. The Permutit Co., 330 West 42nd St., New York.	x			x
	x	Wood: Samples of walnut wood with veneer. American Walnut Manufacturers Assoc., 616 South Michigan Boulevard, Chicago.	x	x		
$2.00		Wool: Wall exhibit of wool in container 18½" long by 7½" wide showing graphically the important processes in the manufacture of worsted yarns. Also samples. Fleisher Yarns, 32–36 Mercer St., New York.	x	x		x

Part III

Sources of Charts and Posters

There follows a carefully selected list of sources of charts and posters which are useful in teaching science. The following is a key to the abbreviations heading the columns:

By . . . . Buy
F . . . . Free
GS. . . . General Science

Bi. . . . Biology
P . . . . Physics
C . . . . Chemistry

How Obtained		Description of Material	Suitable for			
By	F		GS	Bi	P	C
	x	Abrasives: India Wall chart showing various India oil-stones. Approx. 18″ × 18″. Behr-Manning Corporation, Troy, N. Y.	x		x	
	x	Batteries: Edison cell wall chart showing the construction of the Edison-Iron-Alkaline Storage cell. Thomas A. Edison, Inc., Edison Storage Battery Division, West Orange, N. J.	x		x	x
$2.50 each		Birds: Four Audubon Bird Charts of various birds. Audubon Societies, 1974 Broadway, New York.	x	x		
	x	Birds: Two colored wall charts of native birds. One bird banner for classroom use. Church and Dwight Company, Inc., 70 Pine St., New York.	x	x		
	x	Carbonization of Coal: Shows the relation of coal carbonization to industry. Approx. 42″ × 24″. Very interesting and technical wall chart. Koppers Co., Tar and Chemical Division, Pittsburgh, Pa.	x	x	x	x
	x	Cattle-Breeding: Breed charts of Jersey types of cattle. American Jersey Cattle Club, New York.	x	x		

How Obtained		Description of Material	Suitable for			
By	F		GS	Bi	P	C
	x	Cattle-Breeding: Breed charts of Holstein types of cattle. Holstein-Friesian Association, Brattleboro, Vt.	x	x		
$0.25		Chemicals, Organic: Chart, 22″ × 8½″, shows chemical transformations of aliphatic and aromatic series. Fisher Scientific Co., Pittsburgh, Pa.				x
$5.00		Chemicals: Chart, approx. 42″ × 62″, of chemical indicators in color and supplied on rollers. Henry Heil Chemical Co., St. Louis, Mo.	x	x		x
$2.25		Chemical Elements: A chart giving the chemical elements with their atomic weights and numbers. W. M. Welch Scientific Co., Chicago, Ill.	x		x	x
	x	Chocolate: Wall chart, approx. 36″ × 36″, showing products used in making chocolate. Chocolate Sales Corporation, 19 East Chocolate Ave., Hershey, Pa.	x	x		x
	x	Coal: Wall chart, approx. 18″ × 18″, showing products derived from coal. Barrett Co., 40 Rector St., New York.	x	x		x
$0.20		Cotton: Wall chart on cotton. Johnson & Johnson, New Brunswick, N. J.	x	x		x
	x	Cream of Tartar: Chart, approx. 27″ × 37″, mounted. Shows making of cream of tartar. Royal Baking Powder Co., 100 East 42nd St., New York.	x	x		x
	x*	Electrochemical Series: Chart of the electrochemical series. Henry Heil Chemical Co., St. Louis, Mo.	x	x	x	x
$1.00		First Aid: Chart of emergency instructions, approx. 27″ × 44″. Johnson & Johnson, New Brunswick, N. J.	x	x	x	x

* Given with order of chemicals.

How Obtained		Description of Material	Suitable for			
By	F		GS	Bi	P	C
	x	First Aid: Laboratory emergency chart, approx. 16″ × 25″. Fisher Scientific Co., Pittsburgh, Pa.	x	x	x	x
	x	First Aid: Laboratory posters, approx. 8½″ × 11″. National Safety Council, 168 North Michigan Ave., Chicago.	x	x	x	x
$0.50		Flour: Pillsbury pictorial milling chart. Pillsbury Flour Mills Co., Minneapolis, Minn.	x	x		
	x	Food: "Food Source Map of the U. S.," a wall chart, approx. 36″ × 24″. Armour & Co., Chicago.	x	x		x
	x	Food: "Educational Exhibit #414." California Fruit Growers' Exchange, Box 530, Station C, Los Angeles, Calif.	x	x		x
	x	Food: "The Story of Evaporated Milk," a wall chart of the manufacturing process. Evaporated Milk Association, 231 South La Salle St., Chicago.	x	x		x
	x	Food: "How to Make Good Bread." Illustrates every step in the process. Northwestern Yeast Co., Chicago.	x	x		x
$0.12 each		Food: "Milk Made the Difference." Posters showing effects of diets on rats, dogs. National Dairy Council, 370 North Michigan Ave., Chicago.	x	x		x
	x	Food: Cereal charts (5) showing the manufacture of cereal products. Postum Cereal Co., Battle Creek, Mich.	x	x		x
$0.15 per copy		Food: The vitamins given on a miniature chart. Science News Letter No. 370, (Page 292, May 12, 1928), 21st and B Sts., N. W., Washington, D. C.	x	x		x

How Obtained		Description of Material	Suitable for			
By	F		GS	Bi	P	C
	x	Foot Health: Six charts, approx. 18″ × 24″, in colors, showing the anatomical structure of the foot. Cantilever Corporation, 410 Willoughby Ave., Brooklyn, N. Y.	x	x		
x	x	Forest Preservation: Posters for educational purposes on the saving of forests. National Fire Protection Association, 40 Central St., Boston, Mass.	x	x		
	x	Grain: Wall chart, approx. 18″ × 18″, showing excellent colored illustrations of the development of black stem rust. Conference for the Prevention of Grain Rust, 300 Lewis Building, Minneapolis, Minn.	x	x		
	x	Grain: Wall "Mill Chart" showing a wheat and flour-producing plant. Very instructive. General Mills, Inc., 323 Fourth Avenue, South, Minneapolis, Minn.	x	x		
	x	Grain: Wall chart, approx. 30″ × 24″, showing the wheat grain through various conversion steps to flour. Northwestern Consolidated Milling Div., 1013 Metropolitan Life Building, Minneapolis, Minn.	x	x		
	x	Grain: "The Nutriment in a Grain of Wheat," wall chart, approx. 24″ × 39″, showing longitudinal section of a grain of wheat. Excellent for biology. Ralston Purina Company, St. Louis, Mo.	x	x		
	x	Health: Wall charts, "Milk" and "Life Line Chart." Fine for health studies, particularly building weight. Borden's, 350 Madison Ave., New York.	x	x		x
	x	Health: Small wall chart, approx. 12″ × 12″, on "Clean Hands Campaign" (the use of Lifebuoy Soap). Lever Brothers Co., Cambridge, Mass.	x	x		

How Obtained By	How Obtained F	Description of Material	Suitable for GS	Bi	P	C
	x	Insects: Chart showing control of the corn-borer. Other charts of harmful insects. Bureau of Entomology, U. S. Dept. of Agriculture, Washington, D. C.	x	x		
	x	Insects: "The House Fly," a chart in two colors, approx. 16″ × 20″, showing method of extermination. U. S. Public Health Service, Washington, D. C.	x	x		
	x	Meat: "Wilson's Meat and By-Products Charts," approx. 12″ × 12″, showing various cuts of meats. Wilson & Company, 4100 South Ashland Ave., Chicago.	x	x		
	x	Meters: Set of wall charts, approx. 18″ × 18″, on the construction of various electrical recording devices. Weston Electrical Instrument Corp., Newark, N. J.	x		x	
$0.25		Metric System: Chart approx. 25″ × 41″, giving the relative sizes of English and Metric units. Superintendent of Documents, Washington, D. C.	x	x	x	x
$0.50		Oils and Drugs: Flow chart showing derivatives of oils of Citronella, Java, and Ceylon with accompanying set of 19 samples of derived products. Magnus Mabee and Reynard, Inc., 32 Cliff Street, New York.	x	x		x
	x	Optical Instruments: Large chart showing the microscope with construction and smaller charts for students. Bausch & Lomb Optical Co., Rochester, N. Y.	x	x	x	x
	x	Optical Instruments: "Spencer Microscope Chart" showing construction of the microscope. Spencer Lens Company, Buffalo, New York.	x	x	x	x
$5.00		Periodic Chart: Periodic chart of the atom. M. W. Welch Scientific Co., 1516 Orleans St., Chicago.	x		x	x

How Obtained		Description of Material	Suitable for			
By	F		GS	Bi	P	C
$4.00		Periodic Table: Chart, 42″ × 62″, mounted on rollers. Henry Heil Chemical Co., St. Louis, Mo.	x		x	x
$18.50 per set		Plant Charts: Plant charts for teachers. A botanical aid supplied with stand and notebook guide. Western Publishing House, 440 South Dearborn St., Chicago.	x	x		
	x	Plastics: "Chart of Milk Products," small size, showing derivation of Rennet casein used in making "Aneroid" (a plastic). American Plastics Corp., 50 Union Square, New York.	x	x		x
	x	Portland Cement: "Picturing the Manufacturing of Cement." A wall chart approx. 12″ × 48″, showing the technical operations used in making cement from the quarry to the finished product. Lehigh Portland Cement Co., Allentown, Pa.	x			x
	x	Safety: Charts for posting, approx. 12″ × 12″ illustrating the principles of safety. Metropolitan Life Insurance Co., 1 Madison Ave., New York.	x			
	x	Soil: "Lime Needs of Soil." Charts on the uses of lime. National Lime Association, Washington, D. C.	x	x		x
	x	Storage Batteries: Large chart, 41″ × 82″, showing construction of electric storage battery. Electric Storage Battery Company, Philadelphia, Pa.	x		x	x
	x	Teeth: Wall chart, approx. 24″ × 36″, showing arrangement of teeth and their care. Well illustrated. Shows method of cleaning teeth and brushing the teeth. Johnson & Johnson, Tek Tooth Brush Division, New Brunswick, N. J.	x	x		

How Obtained		Description of Material	Suitable for			
By	F		GS	Bi	P	C
	x	Tools: Set of wall charts, approx. 18″ × 18″ on hand saws, files, and hacksaws. Henry Disston & Sons, Inc., Philadelphia, Pa.	x		x	
$2.50 each		Wild Flowers: Charts 1 and 2 each contain 25 pictures in colors. The Garden Club of America, 598 Madison Ave., New York.	x	x		
2 for $0.05		Wild Flowers: Posters on wild flowers. Wild Flower Preservation Society, 3740 Oliver Street, N. W., Washington, D. C.	x	x		
x*		Zoological Charts: "Leukart's Zoological Charts." "Jung's Zoological Charts." These show many botanical and zoological subjects. Kny-Scheerer Co., 10 West 25th St., New York, or J. L. Hammett Co., 380 Jelliff Ave., Newark, N. J.		x		

* Write for price list.

Part IV

Sources of 16 mm. Science Films

This chapter contains a selected list of 16 mm. motion pictures useful in teaching science. The following is a key to the abbreviations used as headings of the columns of data:

By . . . . Buy
R . . . . Rent
F . . . . Free
Si . . . . Silent
So . . . . Sound
Area . . . . Distribution
GS . . . . General Science
Bi . . . . Biology
P . . . . Physics
C . . . . Chemistry
Nat. . . . . National
Spec. . . . . Special
Gen. . . . . General

How Obtained			Title	Si	So	Source	Area	Suitable for			
By	R	F						GS	Bi	P	C
		x	"Erection of Goodyear Zeppelin Steel Hangar" (1 reel)	x		American Institute of Steel Const., Inc., 200 Madison Ave., New York.	Nat.	x		x	x
			"Development of the Battle deck Steel Plate Floor" (1 reel)	x				x		x	x
			Other construction subjects.								
		x	"All American Soapbox Derby," 1935–1936.		x	American Soapbox Derby, Natl. Hdqrs. Chevrolet Motor Car Company, A–223, General Motors Building, Detroit, Mich.	Nat.	x		x	
		x	"From Hatchery to Creel" 50 reels now being produced for early distribution. (Fish & Game)	x		Calif., State of, Div. Fish & Game, Dept. of National Resources, 510 Russ Building, San Francisco, California.	All of Calif.	x	x		

How Obtained			Title	Si	So	Source	Area	Suitable for			
By	R	F						GS	Bi	P	C
x	x	x	Livestock (13 subjects)	x		Canadian Gov't, Dept. of Agriculture, Ottawa, Canada.	Everywhere. 25¢ service charge per subject.	x	x		
			Experimental Farms (2 subjects)	x				x	x		
			Dairy & Cold Stor. (1 subject)	x				x	x		x
			Entomological (1 subject)	x					x		
			Fruit (2 subjects)	x				x	x		
			Forestry (2 subjects)	x				x	x		
			And many others.								
x	x	x	Forestry, etc.	x		Canadian Forestry Association, Standard Bank Building, Ottawa, Canada.	Everywhere.	x	x		
x		x	"Under the 4-H Flag" (7 reels)		x	The Venard Organization, 702 S. Adams St., Peoria, Ill.	Nat. direct.	x	x		
			"4–H News Reel" (1 reel)		x			x	x		
			"Partners Three" (4 reels)	x				x	x		
			"The Valuable Enemy" (2 reels)	x				x	x		
		x	Complete selection of health and hygiene pictures for adults and children.	x		Illinois, State Dept. of Public Health, State House, Springfield, Ill.	Ill. only.	x	x		
x		x	"Ethyl Alcohol"	x		Industrial Alcohol Institute, Inc., 420 Lexington Ave., New York.	Nat. thru DeFrenes & Co., Wilkes-Barre, Pa.				x
		x	"Inland Waterways"		x	Inland Waterways Corporation, 211 Camp St., New Orleans, La.	Nat. direct.	x	x	x	

How Obtained			Title	Si	So	Source	Area	Suitable for			
By	R	F						GS	Bi	P	C
	x		"The Prosperity Process"	x		International Acetylene Assn., 30 East 42nd St., New York.	Spec. to Eng. Sch.	x		x	x
x	x		"Say It with Pearls"	x		Int. Dental Health Foundation for Children, Inc., 130 East End Ave., New York.	Gen.	x	x		
	x	x	"Temples and Tombs of Ancient Egypt"	x		The Metropolitan Museum of Art, 5th Ave. & 82nd, New York.	Free to N. Y. C. public school only.	x			
			"Digging into the Past"	x				x			
			"The Gorgon's Head"	x			Nat. rental basis.	x			
			"Firearms of Our Forefathers"	x				x			
			"The Spectre"	x				x			
			"The Pottery Maker"	x				x			
		x	"Wild Wings"	x		Michigan Dept. of Conservation, Educational Div., Lansing, Mich.	To Mich. groups only.	x	x		
			"Michigan Mammals"	x				x	x		
			"Game Bird Propagation"	x				x	x		
			"Michigan Moose"	x				x	x		
			"Wonder Isle"	x				x	x		
			"Logs and Lumber"	x				x	x		
			"Fish for Food and Sport"	x				x	x		
			"Rainbow Trout"	x				x	x		
			"Fire—The Red Poacher"	x				x	x		
		x	Large collection. Ask for list.	x		New Jersey State Museum, Dept. of Conservation & Developments, Trenton, N. J.	N. J.	x	x	x	x
		x	Several health, hygiene, and dental hygiene subjects. Write for list.	x		New York, State Dept. of Health, State Office Bldg., Albany, N. Y.	New York State only.	x	x		x

How Obtained			Title	Si	So	Source	Area	Suitable for			
By	R	F						GS	Bi	P	C
x	x		"T. R. Himself"	x		Roosevelt Memorial Association, Miss Manning, Dir., 28 East 20th St., New York.	Nat.	x	x		
			"Roosevelt Friend of Birds"	x				x	x		
			"Roosevelt Great Scout"	x				x	x		
			"Roosevelt Dam"	x				x	x	x	
x	x		"Life History of the Monarch Butterfly"	x		Society for Visual Education, 327 La Salle St., Chicago.	Nat.		x		
			"Field and Wayside Wasps"	x					x		
			"Samia Cecropia"	x					x		
			"Great American Silkworm"	x				x	x		
			"Pond and Stream Life"	x				x	x		
			"The Black and Orange Garden Spider"	x				x	x		
			"The Earth and Worlds Beyond"	x				x	x	x	
			"Study of a Mountain Glacier"	x				x	x	x	
			"The Work of Rivers"	x				x	x	x	
			"Dairy Cattle"	x				x	x		
			"Breeds and Characteristics"	x				x	x		
			Also other subjects.								
		x	"Norris Dam" (3 reels) Several additional subjects.	x		Tennessee Valley Authority, Motion Picture Section, Union Building, Knoxville, Tenn.	Nat.	x		x	
		x	"Sulphur"	x		U. S. Bureau of Mines, 4800 Forbes St., Pittsburgh, Pa.	Nat. Write for list.	x			x
			"Asbestos"	x				x			x
			"Manufactured Abrasives"	x				x			x
			"Fire Clay Refractories"	x				x			x
			"Story of Gasoline"	x				x			x
			"Transportation"	x				x		x	
			"Story of the Gasoline Motor"	x				x		x	x

How Obtained			Title	Si	So	Source	Area	Suitable for			
By	R	F						GS	Bi	P	C
			(*Continuing*)								
			"Story of a Storage Battery"	x				x		x	x
			"Heat Treatment of Steel"	x				x		x	x
			"Story of a Spark Plug"	x				x		x	
			"Story of Power"	x				x		x	
			"Story of Lead Smelting"	x				x		x	x
			"Story of Nickel"	x				x		x	x
			"Story of Copper"	x				x		x	x
			"Story of Iron"	x				x		x	x
			"Carbon Monoxide"	x				x			x
			"Unseen Danger"	x				x			x
			"Refining the Crude"	x				x			x
			"Silver-Heirlooms of Tomorrow"	x				x			x
			"Valves—Their Manufacture and Uses"	x				x			x
			"The Story of Steel"	x				x		x	x
			"Learn and Live" (First Aid)	x				x	x	x	x
			"Automobile Lubrication"	x				x		x	x
			"The Metals of a Motor Car"	x				x		x	x
			"The Evolution of the Oil Industry"	x				x			x
		x	Agriculture. 105 subjects on agriculture, stock, forestry, markets.			U. S. Dept. of Agriculture, Extension Service, Office of Motion Pictures, Washington, D. C.	Thru local county agric. agent. Pay for transportation.				
			"ABC of Forestry"		x			x	x		
			"Forest Fires—or Conservation"		x			x	x		
			"The Forest and Health"		x			x	x		
			"The Forest and Water"		x			x	x		x
		x	"Home"		x			x	x		
			"Roads to Wonderland"		x			x	x		

How Obtained			Title	Si	So	Source	Area	Suitable for			
By	R	F						GS	Bi	P	C
			(*Continuing*)								
			"Regulated Deer Hunting"		x			x	x		
			"Flyways of Migratory Waterfowl"		x			x	x		
			"Farm Women's Markets"	x				x	x		
			"Irrigation"	x				x	x		
			"Trail Riders of the Wilderness"	x				x	x		
			Write for complete list.								
		x	"Safety on the Federal Skyways"	x		U. S. Dept. of Commerce, Bureau of Air Commerce, Washington, D. C.	Nat.	x		x	
		x	"Outdoors in the Garden State" (N. J.)	x	x	U. S. Dept. of Interior, National Park Service, Washington, D. C.	Nat.	x	x		
			"Winter Sun & Summer Sea" (Florida)	x	x			x	x		
			"Glimpses of National Parks" (2 parts)	x				x	x		
			"A Visit to Mesa Verde National Park"	x				x	x		
			"Saving the Beauty of Alabama"	x				x	x		
			Write for list.								
x	x		"Western Wild Flowers"	x		Wild Flowers Preservation Society, 3740 Oliver St., N. W., Washington, D. C.	Nat. direct.	x	x		
			"Yosemite Park Flowers"	x				x	x		
			"Orchids, Reeds Growing," etc.	x				x	x		
			"Spare the Dogwood"	x				x	x		
	x		Silent library of hygiene and domestic science.	x		American Museum of Natural Hist., 77 St. & Central Park West, New York.	Nat.	x	x	x	x
			Also of biology, gen. science, physics and chemistry.	x							

How Obtained			Title	Si	So	Source	Area	Suitable for			
By	R	F						GS	Bi	P	C
	x	x	21 reels on nature study	x		Univ. of Arizona, Extension Div., Tucson, Ariz.	Ariz. & adjoining states.	x	x		
			6 reels on agricult.	x				x	x		x
			36 reels on science	x				x	x	x	x
			Instructional SOUND Films. Send for free catalog.		x						
x			"Theory of Flight"	x		Aviation Instruct. Pictures, c/o Henry Bollman, 7 West 44th St., New York.	Nat. to aviat. schools.	x		x	
			"Airplane Engines"	x				x		x	
			"Airplane Structure and Rigging"	x				x		x	
			"Navigation"	x				x		x	
			"Meteorology"	x				x		x	
			"Long Distance Flying"	x				x		x	
			"Aviation Regulation"	x				x		x	
			"Business of Aviat."	x				x		x	
		x	Large library of educational and industrial subjects	x	x	Boston University Free Film Serv., School of Educ., 29 Exeter St., Boston, Mass.	Nat.	x	x	x	x
			Instructional SOUND Films.		x			x	x	x	x
	x		Silent library of physical education, geology, home economics, industrial arts, sciences, etc.	x		Brigham Young University, Bureau of Visual Instruction, Extension Div., Provo, Utah.	Chiefly Utah & South. Idaho.	x	x	x	x
	x		63 subjects available.	x		Bucknell Univ., Classroom Film Library, Lewisburg, Pa.	Pa. schools Rent outside of Pa.	x	x	x	x
	x	x	Over 500 reels. Catalog free on request.	x	x	Univ. of Calif. Extension Div., 301 California Hall, Berkeley, Calif.	Calif.	x	x	x	x
			Also Erpi Instructional SOUND Films.		x						
	x		25 Erpi Instructional SOUND Films on plant life, animal life, physical sci., and natural sci.		x	Columbia College Film Library, Dubuque, Iowa.	Parochial schools nearby.	x	x	x	x

How Obtained			Title	Si	So	Source	Area	Suitable for			
By	R	F						GS	Bi	P	C
x	x		Instructional SOUND Films as follows:		x	Erpi Picture Consultants, Inc.,	Internat. direct				
			Biological Science			250 West 57th St.,	thru				
			"Plant Life"		x	New York.	Univ. of	x	x		
			"Plant Growth"		x		Chic.	x	x		
			"Roots of Plants"		x		Press,	x	x		
			"Flowers at Work"		x		5750 Ellis	x	x		
			"Seed Dispersal"		x		Avenue,	x	x		
			"Fungus Plants"		x		Chic., Ill.	x	x		
			"The Dodder"		x		Rental	x	x		
			"Plant Traps"		x		thru	x	x		
			Animal Life				many				
			"The Frog"		x		Univ.	x	x		
			"Animals of the Zoo"		x		Bureaus of Visual	x	x		
			"How Nature Protects Animals"		x		Instruction.	x	x		
			"Beach and Sea Animals"		x			x	x		
			"Tiny Water Animals"		x			x	x		
			"Butterflies"		x			x	x		
			"Moths"		x			x	x		
			"Beetles"		x			x	x		
			"Pond Insects"		x			x	x		
			"Aphids"		x			x	x		
			"Spiders"		x			x	x		
			Music								
			"The String Choir"		x			x		x	
			"The Woodwind Choir"		x			x		x	
			"The Brass Choir"		x			x		x	
			"The Percussion Group"		x			x		x	
			"Jack and Jill in Songland"		x			x		x	
			Physical Sciences								
			"Oxidation and Reduction"		x			x		x	x
			"Molecular Theory of Matter"		x			x		x	x
			"Electrostatics"		x			x		x	
			"Energy and Its Transformations"		x			x		x	
			"Sound Waves and Their Sources"		x			x		x	
			"Fundamentals of Accoustics"		x			x		x	

How Obtained			Title	Si	So	Source	Area	Suitable for			
By	R	F						GS	Bi	P	C
			(*Continuing*)								
x	x		"The Work of Rivers"		x			x		x	
			"Atmospheric Gradation"		x			x		x	
			Natural Sciences								
			"The Earth's Rocky Crust"		x			x	x		
			"The Wearing Away of the Land"		x			x	x		
			"The Work of Running Water"		x			x	x		
			"Animal Life"		x			x	x		
			"Reactions in Plants and Animals"		x			x	x		
			Geology								
			"Ground Water"		x			x	x		
			"Geologic Work of Ice"		x			x	x		
			"Volcanoes in Action"		x			x	x		
			"Mountain Building"		x			x	x		
			Many others in the process of production.								
	x		Nearly 200 reels. Some SOUND, including Erpi Instructional SOUND Films.	x	x	University of Illinois, Visual Aids Service, Urbana, Ill.	Ill.	x	x	x	x
x	x	x	1547 reels. Many SOUND. 350 free. All different subjects.	x	x	International Educational Pictures, Inc., 40 Mt. Vernon St., Boston, Mass.	Nat.	x	x	x	x
	x		Catalog on request. Many subjects. SOUND Films on Physical Science and Natural Science Erpi Productions.	x	x	University of Indiana, Bureau of Visual Instruction, Extension Div., Bloomington, Ind.	Service to Indiana under enrollment plan. Rental to neighboring state.	x	x	x	x

How Obtained			Title	Si	So	Source	Area	Suitable for			
By	R	F						GS	Bi	P	C
	x		"Fungus Plants"		x	Iowa State College,	Iowa and	x	x		
			"Plant Growth"		x	Visual Instruction	neigh-	x	x		
			"Seed Dispersal"		x	Service,	boring	x	x		
			"When the Cows Come Home"		x	Ames, Iowa.	states.	x	x		
			"Sound Waves and Their Sources"		x			x		x	
			"The Iron Mule"	x				x		x	
			"Behavior of Light"	x				x		x	
			"The Skilled Mechanic"	x				x		x	
			"Toads"	x				x	x		
			"Bird Homes"	x				x	x		
			"The Skin"	x				x	x		
			"Cotton Goods"	x				x	x		
			"Coffee"	x				x	x		
			"Street Safety"	x				x	x		
			Many others. Catalog on request.								
	x		Erpi SOUND library of biological science, music, physical science.		x	State University of Iowa, Dept. of Visual Instruction,	Iowa and any other states where	x	x	x	x
			Also silent library on science subjects and safety.	x		Extension Div., Iowa City, Iowa.	local film service is not available.	x	x	x	x
		x	Large library.	x		Board of Education, Dept. of Visual Instruction, 203 Studio Bldg., Kansas City, Mo.	Kansas City schools only.	x	x	x	x
x			Psychological films	x		Lehigh University,	By mail	x	x		
			"The Nerve Response"	x		Adelbert Ford,	orders to	x	x		
			"Conditioned Responses"	x		Dept. of Psychology, Bethlehem, Pa.	this address.	x	x		
			"Reaction Time"	x				x	x		
			"Illusion of Movement"	x				x	x		
			"Motor Aptitude"	x				x	x		
			"Intelligence of White Rats"	x				x	x		

How Obtained			Title	Si	So	Source	Area	Suitable for			
By	R	F						GS	Bi	P	C
	x		Films on travel, health, and science.	x		Commonwealth of Massachusetts, Div. of University Extension, State House, Boston, Mass.	Mass. only.	x	x	x	x
	x		Write for list.	x		McMath-Hulbert Observatory, Chicago.	To interested parties only.	x		x	
		x	Films on physiology, health, hygiene, and science.	x		Millersville State Teachers College, Film Library, Millersville, Pa.	In surrounding area.	x	x	x	x
	x		Library of Erpi Instructional SOUND Films. About 200 subjects. Write for catalog.		x	University of Minnesota, General Extension Division, Minneapolis, Minn.	Minnesota and neighboring states.	x	x	x	x
	x		List upon request.	x		University of Missouri, c/o Mrs. Margaret Kimes, Columbia, Mo.	Missouri and neighboring states.	x	x	x	x
	x		Films on travel, health, industrial, Century of Progress.	x		University of North Dakota, Visual Instruction Service, 1724 2nd Ave. N., Grand Forks, N. D.	North Dakota and nearby states.	x	x	x	x
	x	x	Large Library of educational, industrial, and travel subjects.	x		Oakland Public Schools, Visual Instruction Center, Room 22, Administration Building, Oakland, Calif.	Primarily to Oakland schools.	x	x	x	x
	x		Large Library of health, hygiene, science subjects. Instructional SOUND Films to be added.	x	 x	Ohio State Dept. of Education, Visual Instruction Exchange, Columbus, Ohio.	Ohio.	x x	x x	x x	x x

How Obtained			Title	Si	So	Source	Area	Suitable for			
By	R	F						GS	Bi	P	C
x			Psychological Films.	x		Ohio State University, Dept. of Psychology, Columbus, Ohio.	Nat.	x	x		
	x		Scientific films. Also a library of instructional SOUND Films.	x	x	Oregon State System of Higher Education, Dept. of Visual Instruction, Corvallis, Oregon.	To special states. Write for terms.	x x	x x	x x	x x
		x	Large library of classroom subjects.	x		Philadelphia Schools, District of, Office of Supt. of Schools, Philadelphia, Pa.	To Phila. schools only.	x	x	x	x
	x		Erpi Instructional SOUND Film library.		x	St. Ambrose College, Davenport, Iowa.	To eastern Iowa schools.	x	x	x	x
		x	Large library. Write for list.	x		St. Louis Public Schools, Educational Museum, St. Louis, Mo.	To St. Louis Public Schools only.	x	x	x	x
	x		Growing library. SOUND Films on health, hospital, nurses training, science.	x	x	University of Scranton, Film Library, Scranton, Pa.	Primarily to Pa. schools and institutions.	x	x		x
	x	x	List on request.	x		University of South Dakota, Extension Division, Vermillion, S. Dak.	South Dakota.	x	x	x	x
	x		Ask for catalog. Some Erpi Instructional SOUND Films.	x	x	University of Texas, Extension Division, Visual Instruction Bureau, Austin, Texas.	Texas.	x	x	x	x

How Obtained			Title	Si	So	Source	Area	Suitable for			
By	R	F						GS	Bi	P	C
x			47 subjects, 16 mm. sound-on-film. Catalog on request.		x	University of Chicago Press, 5750 Ellis Ave., Chicago.	To Ill., Ind., Iowa, Minn., Kansas, Neb., and others.	x	x	x	x
			Also astronomy films and 16 mm. silent library.	x							
		x	Ask for catalog.	x		University of Utah, Extension Div., Salt Lake City, Utah.	Utah.	x	x	x	x
		x	Forestry and Fish Propagation.	x		State of Wisconsin, Photographic Section, Conservation Department, Madison, Wis.	Nat. Recipient must pay express charges both ways.	x	x		
	x		Large Erpi SOUND and silent library of teaching films. Write for list.	x	x	University of Wisconsin, Bureau of Visual Instruction, Extension Div., Madison, Wis.	Wis. and nearby states.	x	x	x	x
		x	"Haliveroil"		x	Abbott Laboratory, Chicago.	Pa. only.	x	x		x
		x	"Saving Seconds"		x	Aetna Casualty & Surety Company, Hartford, Conn.	Nat. thru branches.	x		x	
		x	"Sailing Sheltered Seas to Alaska"	x		Alaska Steamship Company, Pier 2, Seattle, Wash.	Nat.	x	x		
		x	"Her Father's Flock"	x		Allied Mills, Inc., Chicago.	Nat. direct.	x	x		
		x	"Cementing the Centuries"	x		Alpha Cement Co., Easton, Pa.	East of Miss.	x			x
		x	"Action in the Woods"		x	Allis-Chalmers Manufacturing Co., Milwaukee, Wis.	Nat.	x	x	x	
			"The Evolution of Harvesting"		x			x	x		

How Obtained			Title	Si	So	Source	Area	Suitable for			
By	R	F						GS	Bi	P	C
		x	"Making Wear-ever Cooking Utensils"	x		Aluminum Cooking Utensil Co., Wear-ever Bldg., New Kensington, Pa.	Nat. thru YMCA motion picture bureau.	x			x
		x	"From Rags to Roof"	x		American Asphalt Roof Corporation, 15th St. & Blue River, Kansas City, Mo.	Limited to schools in central states.	x			x
		x	"From Mine to Consumer"	x		American Brass Co., 414 Meadow St., Waterbury, Conn.	Nat. to responsible people.	x			x
		x	"Magic of the Mountains"	x		American Coffee Corporation, 420 Lexington Ave., New York.	Nat. thru YMCA motion picture bureau.	x			x
x		x	"Nature-Builder of Teeth"	x		American Dental Association, 212 East Superior St., Chicago.	Progress Film Co., 2120 Lincoln Park, W., Chicago, Ill.	x	x		
		x	"The Manufacture of Face Brick"	x		American Face Brick Assoc., 130 N. Wells St., Chicago.	Nat.	x			x
		x	"Through Life's Windows"	x		American Optical Company, Southbridge, Mass.	Nat.	x		x	
		x	"The New Continuous Process of Making Iron & Steel Sheets"	x		American Rolling Mills Co., Middletown, Ohio.	Nat.	x			x
x			"Modern Methods of Rug Cleaning"	x		American Rug Cleaning Co., 101 Adeline St., Oakland, Calif.	Nat.	x			x

How Obtained			Title	Si	So	Source	Area	Suitable for			
By	R	F						GS	Bi	P	C
		x	"Industry Salutes Agriculture"	x		American Steel & Wire Company, 208 S. LaSalle St., Chicago.	Nat. thru Atlas Educ. Film Co., S. Blvd., Chic., Ill.	x	x		
		x	Silent and SOUND films available through divisions of Bell Telephone Company.	x	x	American Telephone & Telegraph Co.	Nat.	x	x	x	x
		x	"The Origin & Mining of Anthracite" "The Preparation & Servicing of Anthracite"	x		Anthracite Coal Service, 225 S. 15th St., Philadelphia, Pa.	Nat. thru offices of Anthracite Coal Co.	x	x		x
x	x	x	Large library of educationals, industrials, travel and scenic films.	x		Associated Screen News, Ltd., 5721 Western Ave., Montreal, Quebec.	Canada.	x	x	x	x
		x	"Science Saves the Surface"		x	Bakelite Corp., River Road, Bound Brook, N. J., or 247 Park Ave., New York.	Direct and thru branches.	x			
		x	"The Romance of Glass"	x		Ball Brothers Co., Muncie, Indiana.	Nat. thru YMCA	x			x
		x	"Fertilizer from Coal"	x		The Barrett Co., 40 Rector St., New York.	Rothbaker Film Corp., 7510 N. Ashland Ave., Chic., Ill.	x			x
		x	"Glass Magic" "The Eyes of Science"	x x		Bausch & Lomb Optical Company, Rochester, N. Y.	Thru local B & L dealers.	x x		x x	

How Obtained			Title	Si	So	Source	Area	Suitable for			
By	R	F						GS	Bi	P	C
		x	"Seed Disinfection Increases Your Grain Profits"	x		Bayer-Semesan Co., Du Pont Bldg., Wilmington, Del.	Nat.	x	x		
			"Better Quality Vegetables Thru Disease Control"	x				x	x		
		x	"The Story of a Famous Coal"		x	Bell & Zoller Coal Company, 307 N. Michigan St., Chicago.	Nat.	x	x		x
		x	"Making an All Steel Automobile Body"	x		Edward G. Budd Manufacturing Co., Philadelphia, Pa.	Nat.	x		x	x
		x	"Making of Speed Radio Tubes"	x		Cable Radio Tube Corp., 90 N. 9th St., Brooklyn, N. Y.	Nat.	x		x	
		x	"The Jewels of Industry"	x		Carborundum Co., Niagara Falls, N. Y.	Nat. to schools thru U. S. Bureau of Mines and YMCA Bureau.	x		x	x
			"The Story of the Manufacture and Uses of Abrasives and Abrasive Products"	x				x		x	x
		x	"Show Down"		x	Caterpillar Tractor Co., Peoria, Ill.	Nat.	x	x	x	
			"Crops or Canyons"		x			x	x		
			"Pulling Power"		x			x		x	
			"Timber"		x			x	x		
			"When Winter Comes"		x			x	x		
			"Power for Every Farm Job"		x			x		x	
			"Power and Progress"		x			x		x	
		x	"Along the Firing Line"		x	Champion Spark Plug Company, Toledo, Ohio.	Nat. thru U. S. Dept. Commerce, Pittsburgh, Pa.	x		x	x

How Obtained			Title	Si	So	Source	Area	Suitable for			
By	R	F						GS	Bi	P	C
		x	22 films on the telephone. Some SOUND.	x	x	Chesapeake & Potomac Telephone Company of West Virginia, Washington, D. C.	Thru any C & P office.	x		x	
		x	Educational news and mechanical pictures.		x	Chevrolet Motor Company, Div. Gen. Motors, Janesville, Wis.	Direct.	x		x	x
		x	"Preproved by Mac and Me"		x	Chrysler Corp., Dodge Division, Detroit, Mich.	Direct.	x		x	x
		x	"The World and Chrysler Motors" Also others.		x	Chrysler Export Corporation, Detroit, Mich.	Nat. direct.	x		x	x
		x	Write for list.	x		Continental Oil Company, 60 E. 42nd St., New York.	Nat.	x	x		x
		x	"From Cocoon to Spool"	x		Corticelli Silk Company, New York.	Nat. thru YMCA Bureau.	x	x		
		x	"Making Corrective Shoes"		x	Coward Shoes, Inc., Attention: C. C. Mason, 33 West St., Boston, Mass.	N. Y. and Boston. Also to interested parties.	x	x		
		x	"The Milky Way"	x	x	Dairymen's League Cooperative Assoc., Inc., 11 West 42nd St., New York.	Nat.	x	x		x
		x	"Dependability" "Take it Easy"		x x	Dodge Brothers Corporation, Advertising Dept., Detroit, Mich.	Nat. thru dealer.	x x		x x	
		x	"Pigs of Lead" "Eagle Products in the Oil Industry" Others available.	x x		Eagle Pitcher Lead Co., Temple Bar Bldg., Cincinnati, Ohio.	Nat. except West Coast.	x x			x x

How Obtained			Title	Si	So	Source	Area	Suitable for			
By	R	F						GS	Bi	P	C
		x	One reel on electric arcs.	x		Electric Arc Cutting and Welding Co., 152 Jelliffe Ave., Newark, N. J.	Nat.	x		x	x
		x	"Elgin Presents Time"	·	x	Elgin Watch Co. Elgin, Ill.	Castle Film Co., Wrigley Bldg., Chic., Ill.	x		x	
x		x	"Drinking Health"	x		Films of Commerce Co., Inc., 35 West 45th St., New York.	Nat.	x	x		x
			"Cane Sugar"	x				x	x		x
			"Cotton"	x				x	x		x
			"Food Distribution"	x				x	x		x
			Other SOUND-on-film features.		x			x	x		x
		x	"Play Ball"		x	Fisher Body Corporation, Detroit Div., Gen. Motors Corp., Detroit, Mich.	Nat. and thru American League Hdqrtrs., Chic., Ill.	x			
			"Take Me Out to the Ball Game"		x			x			
		x	"Mother Learns Her Lesson"	x		General Baking Co., 420 Lexington Ave., New York.	Nat. direct.	x	x		x
	x	x	"The Electric Shop"		x	General Electric Co., Visual Instruction Section, 1 River Road, Schenectady, N. Y.	Nat. thru Company offices.	x		x	
			"Conquest of the Cascade"		x			x		x	
			"Liquid Air"		x			x		x	x
			"Brighter Times Ahead"		x			x		x	
			"Mountains of Copper"		x			x			x
			"The Cathode Ray Tube"		x			x		x	
			"The Life of Edison"		x			x	x	x	x
			"Magic vs. Science"	x				x	x	x	x
			Many others. Write for list available from *local* visual instruction section of the G. E. Co.								

How Obtained			Title	Si	So	Source	Area	Suitable for			
By	R	F						GS	Bi	P	C
		x	"The Story of Rubber"	x		The B. F. Goodrich Company, Contact nearest branch office, or Akron, Ohio	Nat. thru YMCA Bureau or local office.	x			x
			"Highway Patrol"		x			x			
		x	Write for list. Many films on the uses of rubber.	x		Goodyear Tire & Rubber Co., Motion Picture Div., Akron, Ohio, or Los Angeles, Calif.	Nat. direct.	x			x
		x	"On the Slopes of the Andes"		x	Great Atlantic & Pacific Tea Co., Chicago.	Nat.	x	x		
		x	"The Voice of Business" (Paper Mfg.)	x		Hammermill Paper Co., Erie, Pa.	Nat. to schools.	x	x		x
		x	"Manufacturing of Refractories"	x		Harrison-Walker Refractories, 1800 Farmers Bank Building, Pittsburgh, Pa.	Nat. to schools.	x		x	x
x	x		"The Romance of a Feminine Monarchy" (Honeybees)	x		F. H. Hartman & Son, Photo Dept., 25 N. Baldwin, Sierra Madre, Calif.	West Coast.	x	x		
		x	"The Search of the Elusive Vitamins A and D" (3 reels)	x		Health Products Corporation, 113 N. 13th St., Newark, N. J.	Nat. to schools.	x	x		x
		x	"The Explosives Engineer"	x		Hercules Powder Co., Inc., Motion Picture Dept., Wilmington, Del.	Nat. thru office of company.	x		x	x
			"Rubbing the New Alladin's Lamp"	x				x		x	x
			"Electric Blasting Caps"	x				x		x	x
			"Modern Hercules"	x				x		x	x
			"Story of Nitrocellulose"	x				x		x	x
			Several others. Write for list.								

How Obtained By	R	F	Title	Si	So	Source	Area	Suitable for GS	Bi	P	C
		x	Library of chicken and turkey raising subjects. List on request.	x		Hubbard Milling Co., Mankato, Minn.	Nat. direct.	x	x		
		x	"Making of Lenses"	x		Hugo Meyer, Inc., 245 West 55th St., New York.	Nat.	x		x	
		x	"Farmall Farming Marches On"		x	International Harvester Co., 606 South Michigan Ave., Chicago.	Nat.	x	x		
			"Farming the Farmall Way"		x			x	x		
			"Farm Inconveniences"		x			x	x		
			"International Harvester at A Century of Progress"		x			x	x		
			"International Power in Industry"		x			x		x	
			"Internationals on the Job"		x			x		x	
			"Looking into the Farmall 12"		x			x		x	
			"Pay Dirt"		x			x	x	x	
			"Soybeans for Farm and Industry"		x			x	x		
			"Terracing to Save Our Farms"		x			x	x		
			"The Building of Boulder Dam"		x			x		x	
			"The Farmall Does the Job"		x			x	x		
			"The International Harvester Diesel"		x			x		x	x
			"The McCormick Deering Corn Planter Tells Its Own Story"		x			x		x	x
			"The Story of Binder Twine" (All SOUND-on-films)		x			x	x		
		x	"Guarding Your Health"	x		R. W. Jones, Inc., 70 E. Ferry St., Buffalo, N. Y.	Spec. counties of N.Y. only.	x	x		

How Obtained			Title	Si	So	Source	Area	Suitable for			
By	R	F						GS	Bi	P	C
		x	Three reels on paper making.	x		Kalamazoo Vegetable Parchment Co., Kalamazoo, Mich.	Nat.	x	x		x
		x	Silent and SOUND-on-film subjects on glass.	x	x	Kerr Glass Mfg. Co., 720 Title Ins. Bldg., Los Angeles, Calif.	Nat.	x			x
		x	"Clean Tooth Story" "Priceless Pearls"	x x		Kolynos Toothpaste Co., New Haven, Conn.	Nat. thru YMCA motion picture bureau.	x x	x x		
		x	Films on arc-welding of pipe lines.	x		The Lincoln Electric Co., 12818 Coit Road, Cleveland, Ohio.	Nat.	x		x	
		x	Many films on oxywelding methods.	x		The Linde Air Products Co., 205 East 42nd St., New York.	Nat. direct.	x		x	x
		x	"Advent of Anasthetic Ether" "Manufacture of Anasthetic Ether"	x x		Mallinckrodt Chemical Works, St. Louis, Mo.	Progress Film Co., 2120 Lincoln Park, W. Chic., Ill.				x
		x	"Petroleum"		x	Mid-Continent Petroleum Corp., Cosden Bldg., Tulsa, Okla.	Nat.	x	x		x
		x	"Safety on the Streets"	x		Minnesota Highway Patrol, Highway Bldg., St. Paul, Minn.	Nat.	x			
		x	"Cotton from Seed to Cloth"	x		Nashua Mfg. Co., P. O. Box 1206, Boston, Mass.	Thru Films of Commerce, 35 West 45th St., N. Y. C.	x	x		x

How Obtained			Title	Si	So	Source	Area	Suitable for			
By	R	F						GS	Bi	P	C
		x	"Back of the Button"	x		National Electric Light Assoc., 420 Lexington Ave., New York.	Nat. thru Rothbacker Film Corp., 7510 N. Ashland Avenue, Chic., Ill.	x		x	
			"Yours to Command"	x				x		x	
		x	"What Price Painter"		x	National Lead Co., 111 Broadway, New York.	Nat. thru YMCA Bureau.	x			x
			"From Pigs to Paint"		x			x			x
			"Ask Dad, He Knows"		x			x			x
		x	Silent and SOUND films on telephone communication. (SOUND-on-film and SOUND-on-disc. Operators furnished to all film users except schools having own equipment.)	x	x	Northwestern Bell Telephone Co.	Nat. thru branch offices.	x		x	
		x	Travel and scenic pictures.	x		Northern Pacific Railway Co., Passenger Traffic Dept., St. Paul, Minn.	Nat. direct.	x	x		
		x	"The Angel in the Home"	x		Oakland Chemical Co., 59 Fourth Ave., New York.	Nat. thru YMCA Bureau.	x	x		x
		x	"Alternating Current Motor"	x		Otis Elevator Co., 260 Eleventh Ave., New York.	Nat.	x		x	
			"Riding Skyward" Complete list furnished upon request.	x				x		x	
		x	"Outboard Outings"	x		Outboard Motors Corp., Milwaukee, Wis.	Nat. thru YMCA Bureau.	x		x	

How Obtained			Title	Si	So	Source	Area	Suitable for			
By	R	F						GS	Bi	P	C
		x	"The Packard Factory" (8 reels)	x		Packard Motor Car Company, 1580 E. Grand Blvd., Detroit, Mich.	Nat.	x		x	
		x	"Flying the Lindbergh Trail" (2 reels, each 1200 ft.)		x	Pan-American Airways, Inc., District Traffic Manager, 135 E. 42nd St., New York.	Nat. to schools thru branch offices.	x		x	
		x	"A Film of Endurance"		x	Pennzoil Co., Advertising Dept., Oil City, Pa.	Nat. thru Victor Animatograph Corp., Davenport, Iowa.	x			x
			"Farther, Faster, Safer"		x			x			x
		x	"Ready Kilowatt"		x	Phila. Electric Att.: Ella Haines, Director of Visual Education, Film Service, Philadelphia, Pa.	Direct to Eastern States.	x		x	
	x		"Boy Scout Film —The Woodsman"	x		Plumb Axe Co., Philadelphia, Pa.	Thru Wm. J. Ganz Co., 507 Fifth Ave., N. Y. C.	x			
		x	"Everybody's Business"		x	Plymouth Motor Corp., Detroit, Mich.	Thru Wilding Picture Production, 7635 Grand River Ave., Detroit, Mich.	x		x	
			"Plymouth News"		x			x		x	

How Obtained			Title	Si	So	Source	Area	Suitable for			
By	R	F						GS	Bi	P	C
		x	"Presenting the 1936 Pontiac"		x	Pontiac Motor Car Co., Pontiac, Mich.	Nat. thru Promotion Dept. of Co.	x		x	
		x	"Flames, the Red Robber" (2 reels)	x		Pyrene Mfg. Co., Sales Promotion Dept., 560 Belmont Ave., Newark, N. J.	Nat.	x			x
		x x	"Ten Pounds to the Bushel" "Food Shot from Guns"	x x		Quaker Oats Co., 141 W. Jackson Blvd., Chicago.	Nat.	x x	x x		x x
		x	"Getting the Brakes" (SOUND-on-film) "Breaking in on Brake Prosperity" (SOUND-on-disc)		x x	Raybestos-Manhattan, Inc., The Raybestos Div., Bridgeport, Conn.	Nat.	x x			
		x	"Metal of the Ages"	x		Reading Iron Co., 401 W. Broadway, Philadelphia, Pa.	Thru Pathescope Co. of America, Inc., New York.	x			x
		x	"Home of the Wooden Soldiers"		x	Red Cedar Shingle Bureau, 4408–10 White Building, New York.	Nat.	x	x		
		x	"The Manufacture of Steel Wool" "The Sponge Industry"		x x	James H. Rhodes Co., 153 West Austin Ave., Chicago.	Nat.	x x	 x		
		x	Films on dairying and milk.	x		Sheffield Farms Co., Inc., 524–26 W. 57th St., New York.	Metropolitan N. Y. only.	x	x		

How Obtained			Title	Si	So	Source	Area	Suitable for			
By	R	F						GS	Bi	P	C
		x	"It Happens Every Day" "The Progress of Aviation"	x x		Sherwood Bros., Inc., Baltimore, Md.	Nat.	x x		 x	
		x	"Silica Gel"	x		Silica Gel Corp., Baltimore Trust Building, Baltimore, Md.	Nat. thru YMCA Bureau.	x			x
		x	"Partners" Write for list of others.	x	x	Socony-Vacuum Oil Co., 26 Broadway, New York.	Nat.	x			x
		x	Films on fishing and bait.	x		South Bend Bait Co., South Bend, Ind.	Nat.	x	x		
		x	"Ice"	x		So. California Assoc. Ice Industries, 1315 E. 7th St., Los Angeles, Calif.	S. Calif.	x			x
		x	Large list of silent and SOUND.	x	x	Southern New England Telephone Co., 157 Church St., New Haven, Conn.	State of Conn. only.	x		x	
		x	"The Glory of Wings"		x	Spartan School of Aeronautics, Sheridan Road, Tulsa, Okla.	Nat.	x		x	
		x	"Crystals of Commerce" "Sunday Night Supper" "Tea Time Tidbits"	x x x		Standard Brands, Inc., 595 Madison Ave., New York.	Nat.	x x x	x x x		
		x	"The Story of Sperry Rail Service and Detector Car"	x		Sperry Products, Inc., Manhattan Bridge Plaza, Brooklyn, N. Y.	Nat.	x		x	

How Obtained			Title	Si	So	Source	Area	Suitable for			
By	R	F						GS	Bi	P	C
		x	"Automobile Lubrication"		x	Standard Oil Co. of Indiana, 910 Michigan Ave., Chicago.	Nat.	x		x	x
		x	"The Evolution of an Automobile"	x		Studebaker Corp. of America, South Bend, Ind.	Nat. thru YMCA Bureau.	x		x	
			"Champions"		x			x		x	
		x	"Feeding the Nation"	x		Swift & Co., Public Relations Dept., Union Stock Yards, Chicago.	Nat.	x	x		
			"Chickie"	x				x	x		
		x	"Nature's Refrigerant"	x		Union Ice Co., 1315 E. Seventh St., Los Angeles, Calif.	Calif. and Arizona.	x			x
			"Manufacturing Ice"	x				x			x
		x	"Refining Crude Petroleum"	x		Union Oil Co. of California, Union Oil Bldg., Los Angeles, Calif.	All western states.	x			x
			"Behind the Oil Cargo"	x				x			x
			"Modernizing Roads"	x				x			x
		x	"The Romance of Rubber" (4 reels) Condensed version of same in two reels.	x		U. S. Rubber Co., 1790 Broadway, New York.	Nat. thru office of company	x	x		x
		x	"Romance of Rayon"	x		Viscose Co., 171 Madison Ave., New York.	Nat.	x			x
		x	"The World's Write Hand"	x		L. E. Waterman Co., 191 Broadway, New York.	Thru dealer only.	x			
		x	"Charm and Tooth Brushes"	x		Western Company, 402 Randolph St., Chicago.	Nat. thru YMCA Bureau.	x	x		
		x	34 films on the achievements and activities of this company.	x		Western Electric Company, 120 West 41st St., New York.	Nat.	x		x	

How Obtained			Title	Si	So	Source	Area	Suitable for			
By	R	F						GS	Bi	P	C
		x	"The Turbine with the Solid Rotor"	x		Westinghouse Electric and Manufacturing Co., 435 Seventh Ave., Gulf Building, Pittsburgh, Pa.	Nat. direct.	x		x	
			"In His Father's Footsteps"	x				x		x	
			"Dynamic America"	x				x		x	
			"New Frontiers"		x			x		x	
		x	"Glass Insulators"	x		Whittal Tatum Co., 225 Varick St., New York.	Nat.	x		x	x
			"Glass Containers"	x				x		x	x
		x	"The Story of a Storage Battery"	x		Willard Storage Battery Co., 246–286 E. 131 St., Cleveland, Ohio	Nat. thru Dept. of Commerce, Bureau of Mines, Pittsburgh, Pa.	x		x	x
		x	Films on iron, mining, welding, and others.	x		Youngstown Sheet and Tube Co., Youngstown, Ohio.	Nat.	x		x	x
x	x		Travel films. Write for list.	x	x	Bray Pictures Corp., 729 7th Ave., New York.	Nat.	x	x		
x	x	x	"The Story of Steel" Write for list of many others.	x	x	Brown Film Co., 308 S. Harwood St., Dallas, Texas.	Nat.	x			x
		x	Films on science subjects.	x	x	Caravel Films, Inc., 245 W. 55th St., New York.	Nat.	x	x	x	x
x		x	Industrial films.		x	Castle Films, RCA Building, Rockefeller Center, New York.	Nat.	x		x	
x	x	x	Pictures of wild life, industrials, and science subjects.	x		Frank R. Church Films, 829 Harrison Ave., Oakland, Calif.	International.	x	x	x	x

How Obtained			Title	Si	So	Source	Area	Suitable for			
By	R	F						GS	Bi	P	C
x	x		Large list 16 mm. SOUND-on-disc subjects.		x	Columbia Pictures Corp., Att.: 16 mm. Div., 729 Seventh Ave., New York.	Nat. sell direct. Rentals thru dealers.	x	x	x	x
x			Films of educational nature. Fire prevention films.	x	x	Commercial Motion Picture Productions, 8634 Sunset Blvd., Hollywood, Calif.	Nat. direct.	x	x		x
	x		Science pictures of an industrial nature.	x	x	De Frenes & Co., 1909–1911 Buttonwood St., Philadelphia, Pa.	Nat. only to N. Y., Pa., N. J., Md., Del., D. C., Va.	x	x	x	x
x			Eastman Classroom Films.	x		Eastman Kodak Co., Teaching Films Division, Rochester, N. Y.	Nat.	x	x	x	x
x			Traveltalks. Many subjects.		x	Fitz Patrick Pictures, 729 Seventh Ave., New York.	Nat.	x	x		
x	x		SOUND and silent science subjects.	x	x	Harvard Film Service, The Biological Laboratories, Cambridge, Mass.	Nat.	x	x		
x	x		Burton Holmes Travel-Series. SOUND-on-film. Also large library of silent Burton Holmes Travelogues.	 x	x 	Burton Holmes Films, Inc., Att.: Library Dept., 7510 N. Ashland Ave., Chicago.	Nat. direct. No rentals to individuals.	x x	x x		
x	x	x	Biological Films.	x		A. L. Kirkhuff, 148 S. Brand Blvd., Glendale, Calif.	Nat.		x		

How Obtained			Title	Si	So	Source	Area	Suitable for			
By	R	F						GS	Bi	P	C
x		x	Varied subjects.	x	x	McLarty Motion Picture Service, 75 Enola Road, Detroit, Mich.	Nat.	x			
x	x		Biological Films.	x	x	Scientific Film Co., 20 Lanvale Ave., Daytona Beach, Fla.	Nat.	x	x		
x	x		Write for list. Many interesting subjects.	x		Society for Visual Education, Inc., 327 LaSalle St., Chicago.	Nat.	x	x	x	x
x			Special educational and industrial film made to order.	x	x	Victor Animatograph Corp., Film Division, 242 West 55th St., New York.	Sold nat. Rentals thru numerous dealers.	x	x	x	x
x	x		Biological, travel, and scenic films.	x	x	Bell & Howell Co., 1801–15 Larchmont Ave., Chicago.	Nat.	x	x		
x	x		Silent library of educationals on nature study, health and hygiene, general science, and electricity.	x		Herman A. DeVry, Inc., 1111 Center St., New York.	Thru YMCA Bureau.	x	x		
x	x		Scientific films.	x		Edited Pictures System, Inc., 330 W. 42nd St., New York.	Nat. rental basis.	x	x	x	x
	x	x	Industrial and educational films.	x	x	Friendship Film Service, 250 Stuart St., Boston, Mass.	Nat.	x	x	x	x
x	x		Large variety of SOUND and silent films on science, medicine, travel, etc.	x	x	Kodascope Library, Inc., 33 West 42nd St., New York.	International thru branches.	x	x	x	x

How Obtained			Title	Si	So	Source	Area	Suitable for			
By	R	F						GS	Bi	P	C
	x	x	Library of SOUND and 350 silent subjects. 50 SOUND.	x	x	Motion Picture Bureau of the Y.M.C.A., 347 Madison Ave., New York, or 19 S. LaSalle St., Chicago.	Nat.	x	x	x	x
x	x		Travel and exploration films.	x	x	Principal Distributing Corp., 1501 Broadway, New York.	Nat.	x	x		
x	x		Industrials and educationals.	x	x	Roake Film Service, 901 University N., Peoria, Ill.	Ill. and nearby states.	x	x	x	x
x	x		Science films.	x		School Films Service, Inc., 55 West 42nd St., New York.	Nat.	x	x	x	x
	x		Teaching Film Library.	x	x	Visual Education Service, 470 Stuart St., Boston, Mass.	New England states.	x	x	x	x
x	x	x	Library of educational subjects. Write for catalog.	x		J. H. Weil & Co., 1315 Cherry St., Philadelphia, Pa.	Eastern U. S.	x			

Part V

Books and Periodicals for Teachers and Students

LIST OF PUBLISHERS

American Book Company, 88 Lexington Avenue, New York.
American Technical Society, 850 E. 58th St., Chicago.
Appleton: D. Appleton-Century Co., 35 W. 32nd St., New York.
Augustin: J. J. Augustin, 30 Irving Place, New York.
Barnes & Co., 67 W. 44th St., New York.
Bell Telephone Laboratories, 463 West St., New York.
Blakiston's Son & Co., 1012 Walnut St., Philadelphia, Pa.
Bobbs-Merrill Co., 724 N. Meridian St., Indianapolis, Ind.
Bruce Publishing Co., 524 N. Milwaukee St., Milwaukee, Wis.
Camera Craft Publishing Co., 425 Bush St., San Francisco, Calif.
Carrick & Evans, 20 E. 57th St., New York.
Chicago: University of Chicago Press; 5750 Ellis Ave., Chicago.
Christopher Publishing Co., 1140 Columbus Ave., Boston, Mass.
Collins: William Collins Sons & Co., 425 4th Ave., New York.
Columbia University Press, 2960 Broadway, New York.
Crofts & Co., 41 Union Square, W., New York.
Cupples & Leon Co., 470 Fourth Ave., New York.
Dartnell Corp., 4660 Ravenswood Ave., Chicago.
Doubleday, Doran & Co., 74 W. 49th St., New York.
Dutton & Co., 300 Fourth Ave., New York.
Farrar & Rinehart, 232 Madison Ave., New York.
Fortuny's, 67 W. 44th St., New York.
Funk & Wagnalls Co., 354 Fourth Ave., New York.
Ginn & Co., 15 Ashburton Place, Boston, Mass.
Globe Book Co., 175 Fifth Ave., New York.
Greenberg, Publisher, 67 W. 44th St., New York.
Gregg Publishing Co., 270 Madison Ave., New York.
Hale, Cushman & Flint, 116 Newbury St., Boston, Mass.
Harcourt, Brace & Co., 383 Madison Ave., New York.
Harlow Publishing Co., 217 N. Harvey St., Oklahoma City, Okla.
Harper & Brothers, 49 E. 33rd St., New York.
Harvard University Press, 4 Randall Hall, Cambridge, Mass.
Heath & Co., 285 Columbus Ave., Boston, Mass.
Hillman-Curl, 7–11 E. 44th St., New York.
Houghton Mifflin Co., 2 Park St., Boston, Mass.
Humphries, 306 Stuart St., Boston, Mass.

Industrial Press, 140 Lafayette St., New York.
International Textbook Co., 1001 Wyoming Ave., Scranton, Pa.
Johnson Publishing Co., 8 S. Fifth St., Richmond, Va.
Judd Publishing Co., 15 E. 26th St., New York.
Knight Publications, 432 Fourth Ave., New York.
Knopf, Alfred A., 730 5th Ave., New York.
Lea & Febiger, 600 S. Washington Square, Philadelphia, Pa.
Leisure League of America, 30 Rockefeller Plaza, New York.
Lippincott Co., J. B., 227 S. 6th St., Philadelphia, Pa.
Little, Brown & Co., 34 Beacon St., Boston, Mass.
Liveright Publishing Corp., 386 Fourth Ave., New York.
Longmans, Green & Co., 114 Fifth Ave., New York.
Lyons & Carnahan, 2500 Prairie Ave., Chicago.
McGraw-Hill Book Co., 330 W. 42nd St., New York.
McKay Co., 604 S. Washington Sq., Philadelphia, Pa.
McKnight & McKnight, 109 W. Market St., Bloomington, Ill.
Macmillan Co., 60 Fifth Ave., New York.
Manual Arts Press, 237 N. Monroe St., Peoria, Ill.
Meador Publishing Co., 324 Newbury St., Boston, Mass.
Messner, Julian, 8 W. 40th St., New York.
Minnesota: University of Minnesota Press, Minneapolis, Minn.
Modern Age Books, 432 Fourth Ave., New York.
Morrow & Co., 386 Fourth Ave., New York.
National Geographic Society, Hubbard Memorial Hall, 16th & M Sts., N. W., Washington, D. C.
New York Zoological Society, Bronx Park, New York.
Oklahoma: University of Oklahoma Press, Norman, Okla.
Oxford University Press, 114 Fifth Ave., New York.
Page, L. C. & Co., 53 Beacon St., Boston, Mass.
Penn Publishing Co., 925 Filbert St., Philadelphia, Pa.
Penna: University of Pennsylvania Press, 3622 Locust St., Philadelphia, Pa.
Pitman Publishing Co., 2 W. 45th St., New York.
Popular Mechanics Press, 200 E. Ontario St., Chicago.
Prentice-Hall, 70 Fifth Ave., New York.
Princeton University Press, Princeton, N. J.
Putnam's Sons, 2 W. 45th St., New York.
Rand, McNally & Co., 536 S. Clark St., Chicago.
Reilly & Lee Co., 355 W. Huron St., Chicago.
Revell, Fleming H. Co., 158 Fifth Ave., New York.
Reynal & Hitchcock, 386 Fourth Ave., New York.
Sanborn, B. H. & Co., 221 E. 20 St., Chicago.
Saunders, W. H. & Co., W. Washington Square, Philadelphia, Pa.
Scholastic Corp., 402 Chamber of Commerce Building, Pittsburgh, Pa.

Scribner's Sons, Charles, 597 Fifth Ave., New York.
Simon & Schuster, 386 Fourth Ave., New York.
Stackpole Sons, 250 Park Ave., New York.
Stokes, Frederick A. & Co., 443 Fourth Ave., New York.
Studio Publications, 381 Fourth Ave., New York.
Swift, John S. & Co., 105 S. Ninth St., St. Louis, Mo.
University Society, 468 Fourth Ave., New York.
Vanguard Press, 424 Madison Ave., New York.
Van Nostrand Co., 250 Fourth Ave., New York.
Viking Press, 18 E. 48th St., New York.
Webster Publishing Co., 1808 Washington Ave., St. Louis, Mo.
Whitman, A. Albert & Co., 560 W. Lake St., Chicago.
Wiley & Sons, John, 440 Fourth Ave., New York.
Williams & Wilkins Co., Mt. Royal & Guilford Aves., Baltimore, Md.
World Book Co., 313 Park Hill Ave., Yonkers-on-Hudson, N. Y.
Yale University Press, 143 Elm St., New Haven, Conn.

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